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STEAM CONSUMPTION OF THE MAIN AND AUXILIARY MACHINERY OF THE U. S. S. *MINNEAPOLIS.*

PRIZE ESSAY.

BY PASSED ASSISTANT ENGINEER W. W. WHITE, U. S. NAVY.

The apparatus for testing the auxiliaries, which will be described further on, was primarily arranged to find the steam consumption of the dynamo engines. From an inspection of the cylinders, it was known that these engines used an abnormally large amount of steam, due to leakage past the pistons, which were grooved for water packing, and were without packing rings. New pistons, with snap rings, were designed and fitted in the cylinders of one of the three dynamo engines, and tests made to ascertain whether the saving was sufficient to warrant the change in the remaining two. These, and many other tests of the different auxiliaries which were made as a matter of information, are arranged under the head of auxiliary machinery. For convenience of comparison, all results are given in steam

per hour or per I.H.P. per hour, since the evaporative power of coal varies greatly with the variety used.

The method adopted in all experiments was to measure the condensed exhaust steam. In all the auxiliary tests, the manner of carrying this out was practically the same; for determining the steam used by the main propelling engine, the following method was employed.

MAIN STARBOARD ENGINE.—TABLES Nos. I AND II.

Engine.—Inverted, direct-acting, vertical, three-cylinder, triple expansion. Diameter of cylinders, 42, 59 and 92 inches. Stroke (common), 42 inches. Diameter of all piston rods, $8\frac{1}{8}$ inches. I.H.P. on full power trial, 6,587 (for full description, see Volume VI, No. 4, of the JOURNAL).

For the purpose of determining the steam used by this engine, a long glass water gauge was fitted to the starboard feed tank. A wooden batten, painted white with horizontal black marks about one inch from the glands at top and bottom, was secured back of and close to the glass between the glands, and the capacity of the tank between these marks accurately ascertained. Two calibrations of the tank, with the ship on an even keel, showed the capacity between marks to be practically constant at any ordinary trim of the ship. The first, when the ship was 7 inches down by the stern, only differing by three pounds from the second, with the ship 16 inches down by the stern. The total capacity between marks was found to be 5,954 pounds, with the temperature of the measuring water at 82 degrees.

The three main feed tanks are connected by a common feed suction, a valve being placed at each tank, so that all, or any one, may be disconnected as desired. From this common connection, the fire room feed suctions extend on either side to the main or auxiliary feed pumps in the fire rooms. Each main air pump delivers into its own feed tank.

In order to find the length of time required to fill the tank between marks, the starboard engine being in use, it is necessary to shut only the suction valves on the port and center feed tanks, thus permitting the fire room pump to draw entirely from

the starboard tank. Having in this way reduced the water in the starboard tank below the lower mark, its suction valve is closed, and the two on the other tanks opened. All traps discharging into the starboard tank are now temporarily closed off, and the time noted when the water, as delivered from the air pump, reaches the lower and upper marks. These times are recorded in columns 1 and 2 of the tables; column 3 gives the elapsed time. Indicator cards were taken during many of the tests, and these, with the above, furnish the data necessary to compute the steam per hour per I.H.P., providing there has been no leakage of the condenser, or carrying over of water from the boilers, during the tests.

The condenser, however, was not tight, but the leakage, which came from about joints of the tube sheets, which were made in halves and scarfed with an outside butt strap, remained practically constant for a considerable length of time, as will be shown later from results of chemical tests. An attempt was made to ascertain the amount of this leakage immediately after arriving in port, January 1, 1897 (see Table I), by using the center engine main condenser for the usual auxiliaries, all of which exhausted on the port side, the exhaust taking the direction indicated by arrows on plate 1. The two auxiliary exhaust valves on the starboard main condenser were opened to the auxiliary line, and the starboard circulating pump was run at the same speed as when under way. After a certain time the starboard condenser was disconnected, the vacuum broken, and the salt water leakage drained off through the bottom cock. This method was unsatisfactory because the vacuum carried in the auxiliary line was only 17 inches, instead of between 25 and 26 when the main condenser is in regular use, and, as the leakage would depend largely on that factor, the result obtained was evidently too small. It amounted to 413 pounds per hour, while by chemical analysis the leakage was found to be 602.7 pounds.

It is customary during ordinary cruising of the ship to set the speed at a given number of revolutions of the engines, and this being well within the boiler power in use, it is possible by frequent counter observations to maintain the exact number of

TABLE I.—TEST No. 1 OF MAIN STARBOARD ENGINE, DECEMBER 31, 1896, AND JANUARY 1, 1897.

Passage between Alexandretta and Beyrout, Syria.

Wing engines and two main boilers in use. Speed of ship, 8.3 knots; condition of bottom, foul.

Reference letter.	Date.	Time.			Steam pressure.				Cut-off.			Throttle. (Full opening = 1.)	Vacuum.	Revolutions per minute.	Mean pressures.			Indicated horse power.				Condensed steam per hour, pounds.				
					Gauge.		Absolute.																			
		At lower mark.	At upper mark.	Elapsed.	Boiler.	Engine room.	First receiver.	Second receiver.	H.P.	I.P.	L.P.				H.P.	I.P.	L.P.	H.P.	I.P.	L.P.	Total.	Temperature.	At observed rate. (Includes leakage of condenser.)	Leakage of condenser.	Net weight of condensed steam.	Per I.H.P.	Per cent. accounted for from H.P. cards.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	1896	P. M.	h. m. s.	h. m. s.	m. s.																					
A	Dec. 31	5'23'30	5'50'20	26'50	150	140	22	5½	.60	.59	.56	.05	26	52	13.43	6.45	2.37	205.27	196.37	176.47	578.11	82	13,313	602.7	12,710.3	21.986	85.77
B	Dec. 31	6'10'40	6'38'05	27'25	158	147½	21½	5½	.60	.59	.56	.05	25½	53	13.95	7.00	2.70	213.21	213.11	201.04	627.36	82	13,030	602.7	12,427.3	19.809	82.40
	1897	A. M.																								
C	Jan. 1	2'24'40	2'50'10	25'30	140	133	22	5½	.60	.59	.56	.05	25	53	16.82	6.37	2.25	257.09	193.93	167.54	618.56	82	14,009	602.7	13,406.3	21.673	80.24
D	Jan. 1	3'08'16	3'33'59	25'43	145	138	22	5½	.60	.59	56	.05	25	53	...	...	...	...	...	...	...	84	13,891	602.7	13,288.3	...	...
E	Jan. 1	5'35'55	6'02'10	26'15	150	142	22	5½	.60	.59	.56	.05	26	53	...	...	...	...	...	...	...	84	13,609	602.7	13,006.3	...	...
F	Jan. 1	6'21'40	6'48'10	26'30	150	142	21	5	.60	.59	.56	.05	26	53	16.81	6.45	2.23	256.94	196.37	166.04	619.35	80	13,481	602.7	12,878.3	20.793	81.90
G	Jan. 1	7'11'00	7'37'05	26'05	148	140	22	5½	.60	.59	.56	.05	26	53	...	...	...	...	...	...	...	80	13,696	602.7	13,093.3	...	...
	Average.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	610.85	...	13,576	602.7	12,973	*21.237	82.56

Capacity of feed tank between marks at temperature 82° = 5,954 pounds.

* Average steam per hour per I.H.P. for test = $\frac{12,973}{610.85} = 21.237$.

TABLE II.—TEST No. 2 OF MAIN STARBOARD ENGINE, JUNE 26 AND 28, 1897.

Passage between Gibraltar and League Island, Pa.

Wing engines and three main boilers in use. Speed of ship, 10.2 knots: condition of bottom, clean.

Reference letter.	Date.	Time.			Steam pressure.				Cut-off.			Throttle. (Full opening = 1.)	Vacuum.	Revolutions per minute.	Mean pressures.			Indicated horse power.				Condensed steam per hour, pounds.					
					Gauge.		Absolute.																				
		At lower mark.	At upper mark.	Elapsed.	Boiler.	Engine room.	First receiver.	Second receiver.	H.P.	I.P.	L.P.				H.P.	I.P.	L.P.	H.P.	I.P.	L.P.	Total.	Temperature.	At observed rate. (Includes leakage of condenser.)	Leakage of condenser.	Net weight of condensed steam.	Per I.H.P.	Per cent. accounted for from H.P. cards.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	1897	P. M.																									
		h. m. s.	*h. m. s.*	*m. s.*																							
A	June 26	1·38·50	2·01·00	22·10	139	134	22	6¼	.61	.60	.59	.05	26½	60	18.10	7.80	2.50	313.21	268.82	210.74	792.77	82	16,116	197	15,919	20.080	85.65
B	June 26	2·11·25	2·33·10	21·45	145	140	21	5¾	.61	.60	.59	.05	26½	60	18.40	8.00	2.45	318.40	275.72	206.52	800.64	82	16,425	197	16,228	20.269	86.75
C	June 26	2·41·45	3·03·20	21·35	140	135	22	6	.61	.60	.59	.05	26½	60	18.37	7.70	2.35	317.88	265.38	198.10	781.36	82	16,551	197	16,354	20.930	84.34
D	June 26	3·12·50	3·34·50	22·00	145	140	21½	5½	.61	.60	.59	.05	26½	60	18.25	8.20	2.55	315.80	282.61	214.95	813.36	82	16,238	197	16,041	19.721	85.70
		A. M.																									
E	June 28	5·27·25	5·49·40	22·15	145	140	21	5½	.61	.60	.59	.05	27	60	17.25	7.90	2.45	298.50	272.28	206.52	777.30	84	16,055	213	15,842	20.381	80.71
F	June 28	5·59·40	6·21·55	22·15	140	135	22	6	.61	.60	.59	.05	27	60	17.40	7.75	2.25	301.10	267.10	189.66	757.86	84	16,055	213	15,842	20.904	78.77
G	June 28	6·32·35	6·54·55	22·20	142	137	21½	5½	.61	.60	.59	.05	27	60	17.37	7.75	2.35	300.57	267.10	198.10	765.77	84	15,996	213	15,783	20.610	84.27
H	June 28	7·04·05	7·26·35	22·30	145	140	21	5½	.61	.60	.59	.05	27	60	17.50	7.70	2.30	302.82	265.38	193.88	762.08	84	15,877	213	15,664	20.554	81.49
	Average.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	781.39	...	16,164	205	15,959	20.431	83.46

revolutions with but slight and occasional changes of the throttle. During the tests covered by Tables I and II, the engines, port and starboard, averaged 53 and 60 revolutions, respectively, with no sensible variation at any time.

The *Minneapolis* is a remarkably steady ship at sea, and except in rough weather, neither rolls nor pitches, so that the time when the water reached the lower and upper marks on the scale on the starboard feed water tank could be noted to the exact second; and, as no special preparation was required in making these tests, repetition could be made as often as desired without disturbing the usual working of the engine. Many tests, in addition to those given in the tables, were made, the average I.H.P. varying between the limits there shown; these checked very closely with the results recorded. Of course, with the engine developing approximately the designed power, the steam per I.H.P. per hour would have decreased materially, but no opportunity offered to secure such tests.

Leakage of the condenser was determined by chemical analysis of the feed and sea waters. The method employed, with but slight variations, is explained in an article by Mr. C. E. Stromeyer, page 517, Volume VIII of the JOURNAL, and is briefly as follows.

Referring to Table I, samples of the feed and sea waters were taken at 5·30 P. M., December 31, and 6 A. M., January 1 (tests A and E), and the relative amount of salt in these determined. To do this, a burette, a solution of nitrate of silver and a small quantity of potassium mono-chromate solution are required. The test is simple and accurate and, with the above articles in readiness, can be made in a few minutes.

The sample of water to be tested is given a yellow tint by adding a few drops of potassium mono-chromate, and then the previously prepared standard solution of nitrate of silver is dropped from the burette into the receptacle containing the water, until a permanent red precipitate is formed. The burette having been read at the beginning and end of the experiment, the volume of nitrate of silver added to produce the red color is known, from which the number of grains of salt in the sample may be determined. The standard solution used was prepared

by adding, to a litre of distilled water, 4.788 grammes of nitrate of silver. Any other proportion will answer the purpose equally well, unless it is desired to ascertain the absolute amount of salt in the samples of water, in which case the standard solution is more convenient.

The following are the results obtained from the samples of water taken at 5·30 P. M., December 31.

	Feed water.				Sea water.		Distilled water.	
Volume tested, cubic centimeters	10	10	10	10	2	2	100	100
Reading of burette at beginning of test	2.6	12.8	0.9	11.1	0.1	0.0	21.3	22.1
Reading of burette at end of test	12.7	22.8	10.9	21.1	44.4	44.5	22.0	22.8
Difference of burette readings (c. c. of nitrate of silver solution used)	10.1	10.0	10.0	10.0	44.3	44.5	.7	.7
Mean value	10.025				44.4		.7	
C. c. of nitrate of silver solution used per c. c. of water tested	1.0025				22.20		.007	

The sea water, 2 c. c., as given in the column, was diluted to 10 c. c. by adding distilled water before testing, for the reason that the instant of change of color can be more correctly noted with a solution containing a smaller quantity of salt. To insure accuracy in measurement, the 10 c. c., diluted as described, were obtained by mixing 40 c. c. of distilled water with 10 c. c. of sea water, and taking 10 c. c. of the resulting mixture for the test. The object in testing the distilled water was to apply the correction (since it also contained salt in minute quantities) necessary on account of using 8 c. c. of it in the test of the sea water. This correction, however, is ordinarily so small that it may be neglected without sensibly altering the final result.

As before stated, samples of the feed and sea waters were taken also at 6 A. M., January 1. An analysis of these gave practically identical results, per interval of time, with those already described, thus indicating that the condenser leakage remained constant.

If X = The number of pounds of sea water leakage of the condenser per hour.

a = Pounds of condensed steam and sea water collected per hour in feed tank (column 22 in Table).

Then, $X(22.20 - 8 \times .007) = a \times 1.0025$

$$X = \frac{1.0025 \times a}{22.144}$$

From this equation, substituting $a = 13{,}313$ (see test A), the condenser leakage is found to be 602.7 pounds per hour.

It will be observed that only the ratio of the quantities of nitrate of silver solution to produce a permanent change of color in the waters tested is necessary in order to calculate the condenser leakage. Any dilute solution of nitrate of silver, therefore, answers this purpose, though by using the standard solution before mentioned, the number of grains of salt per unit of weight can readily be found. Thus, for every c. c. of the standard solution used in the test, there are contained in the water tested, 1.65 milligrammes of salt; from which it follows that in each pound of sea water of the above test, there were contained 255.7632 grains of salt.

The condenser leakage in Table II was determined in a similar way, samples of water taken on June 26 (tests A, B, C and D), showing 197 pounds, and on June 28 (tests E, F, G and H), 213 pounds per hour. It will be seen that this leakage is only about one-third of that in Table I, a result due to the constant effort made to stop, or minimize, the sea water entering the defective tube sheet joints by frequent coats of asphaltum paint or other substance.

During the test covered in Table I, steam was supplied to the main engines through the auxiliary steam line (5-inch pipe), a connection being made in each wing engine room by proper valves into that part of the main steam line included between the port and starboard engine room bulkheads; the valves on the latter were closed, as were the main boiler stop valves, thus doing away with radiation from the main steam line in the fire rooms. The wing engines could be run in this way at slow

speeds without undue drop of steam pressure between the boilers and engines. In Table II, the main steam line (20-inch pipe) was used.

LOSS OF FEED WATER PER DAY.

It may be of interest to note in this connection the amount of "make-up feed" required per day, each main engine, port and starboard, developing very closely the power recorded in Table II. An experiment extending over a period of three days was made, during which time the engines ran continuously at 60 revolutions.

The exhaust from all auxiliary machinery in use was sent to the main condensers; traps to cylinder jackets, main and auxiliary steam lines, dynamos, evaporator coils, pantry warming pans and galley coppers, discharged into the feed tanks near the bottom. Water in these tanks was not allowed to fall below the 700-gallon mark, in order that the different trap discharges might be well covered and the formation of vapor avoided. Particular attention was given to the steam and water piping and stuffing boxes to prevent leakage.

The only loss apparent was the amount of steam used in heating water for baths and for pantry purposes. This was estimated to be 600 pounds per day.

Deficiency of feed, other than condenser leakage, was supplied from a double bottom compartment, which previously had been carefully calibrated, and from which fresh water could readily be pumped by means of a small special suction to either main air pump. At the beginning and end of the experiment, the reading of the scale on each of the three feed tanks was recorded, as well as the quantity of water in the double bottom. The height of the water in the steaming boilers was also marked, and left at the same level at the end of the test.

A summary of the results is as follows.

Date of beginning of experiment	June 25, 1897, 9 A. M.
end of experiment	June 28, 1897, 9 A. M.
Duration of experiment, hours	72
Quantity of feed water in tanks, June 25, 9 A. M., gallons	2,255
double bottom, June 25, 9 A. M., gallons	7,000

Quantity of feed water in tanks, June 28, 9 A. M., gallons	2,240
double bottom, June 28, 9 A. M., gallons	6,750
Net quantity of feed water used from double bottom, gallons	235
per hour, pounds	27 2
Leakage of port condenser per hour (av. of three chemical tests), pounds,	754.4
starboard condenser per hour (Table II), pounds	205.
Total loss of feed water per hour, pounds	986.6
Average estimated amount used for baths, pantries, etc., per hour, pounds,	25
Net loss of feed water unaccounted for per hour, pounds	961.6
day, tons	10.30
Average I.H.P. of starboard engine during experiment	783.6
port engine during experiment	780 7
auxiliaries in use	67
Loss of feed water per day per 100 I.H.P. developed by main engines, tons,	.658
main and auxiliary machinery, tons	.631

APPARATUS USED IN TESTING AUXILIARY MACHINERY.

Referring to plate 1, where the auxiliary exhaust piping and valves, with the different condenser connections, are outlined, it will be seen that the exhaust may be thrown, by a proper arrangement of valves, into any one of the three main condensers, or to either of the two auxiliary condensers. For the purpose of finding the steam consumption of each of the auxiliaries which follow, the starboard auxiliary condenser was used to condense the exhaust steam and deliver the water of condensation to the upper of two barrels, which were employed in measuring the amount, the exhaust from all other machinery in use at the time being sent to one or more of the other condensers. Generally this could be arranged without in any way disturbing the usual auxiliaries run, either in port or at sea, but sometimes involved stopping certain machinery during the test.

Both auxiliary condensers are horizontal, mounted on a Knowles' combined air and circulating pump of the pattern shown on plate 3, and more particularly described under the test of the starboard auxiliary condenser. The usual delivery pipe from the air pump of the starboard condenser was disconnected, and a hose substituted, which ended in the upper barrel shown in plate 2. By this means all the exhaust steam condensed, from the auxiliary under test, was delivered into this barrel, then drop-

ped to the lower barrel, and finally run by gravity to the feed tank below through a hose connection to the lower barrel. To make it unnecessary to weigh each barrel of water as collected, the lower of the two barrels in the beginning was carefully leveled, and the net weight of water which it contained up to the bevel of the head, accurately ascertained. This was found to be 438.6 pounds, with the temperature of the measuring water at 87 degrees, the capacity being very nearly 52½ gallons. Each barrel of water as collected was run to this mark, the temperature taken, and the proper correction calculated and applied for any difference of temperature. Besides, the capacity of the barrel was measured by means of a gallon measure, and a graduated scale made so as to determine parts of a barrel of water.

The auxiliary condensers are placed directly under the wing engine room armor gratings, 15 feet above the engine room floor, and the top of the upper barrel, to which height the condensed water had to be delivered by the air pump, was 16 feet above the delivery opening of the pump. The upper barrel rested on and was secured to an engine room grating, and the lower barrel was made fast to the armor grating below. As there was no more difficulty in making tests with the ship at sea than in port, some of the auxiliaries, such, for instance, as the starboard main air and circulating pumps and boiler feed pump, were thus tested in regular use.

The arrangement of exhaust piping was such, when the tests were first undertaken, that the exhaust from the steam cylinder driving the starboard auxiliary air and circulating pumps had to be included in the water collected. By a change made on November 25, 1896, the exhaust from this cylinder was altered to run direct to the port auxiliary condenser, so that in all tests after that date, only the condensed exhaust steam from the auxiliary under test was collected, the port condenser being always put in operation, if for no other purpose than to condense the exhaust of the starboard, and that of its own steam cylinder. In tests, other than the dynamos, where there was a choice between a number of the same sized auxiliaries, one was preferably selected, the exhaust of which connected to the star-

board side of the auxiliary line, and hence by closing the valve *B* (plate 1) the port condenser took the exhaust of all the auxiliaries in use, except the one being tested.

A somewhat different arrangement was necessary in making tests of the dynamo engines. As the exhaust from these joined the auxiliary exhaust line only on the port side forward, no part of the auxiliary exhaust line forward of the forward bulkhead of the center engine room could be utilized except for the test. This restricted the use of machinery, which was to be in operation during the time, to the center engine room auxiliaries, and made it necessary to direct the exhaust from these into the center main condenser. This presented no difficulty other than closing down some of the auxiliaries which were generally run, such as the ventilating blowers, ice machine, distilling plant, &c. The essential auxiliaries, a boiler feed pump and flushing pump, were operated from the center engine room. Before the change of exhaust piping to the steam cylinder of the starboard condenser, mentioned above, that auxiliary condenser alone was run during dynamo tests, its exhaust being a part of the water collected.

Particular attention was given to carry about the same vacuum in all parts of the auxiliary exhaust line during tests, in order to prevent the possibility of leakage past the valves. Frequent experiments, after the exhaust from the steam cylinder of the starboard condenser was altered, showed that there was little chance of this occurring. Thus, for example, before starting a test, everything being in readiness with the different valves arranged in the auxiliary exhaust line, and just preliminary to putting the auxiliary to be tested in operation, the vacuum in the starboard auxiliary condenser would be purposely made much greater than in the port condenser, and the starboard auxiliary air pump failing to deliver any water proved the system to be tight. Such tests were repeated at intervals, but, under the widest variation of vacuum obtainable, no leakage was discovered; in addition, many nitrate of silver tests of the water delivered by the starboard air pump were made but showed no trace of salt.

The auxiliary steam line, from which all auxiliary machinery is supplied, runs much in the same way as the exhaust line,

branches to the different auxiliaries being generally led from the top of this pipe, though in some cases the connection is made to the side. In either instance, however, it is quite improbable that water (due to condensation or other causes) in the auxiliary steam line would reach any auxiliary engine running, particularly as the pipe is well drained throughout its length by a system of drain pipes leading to three traps.

The manner of conducting the tests was as follows. Having arranged the valves in the exhaust line and found the system tight, the auxiliary to be tested was started, but, before beginning to record data, sufficient time was allowed to elapse to insure regular normal working conditions. During this period, usually one-half hour at least, the condensed exhaust steam delivered by the starboard auxiliary air pump was permitted to run to the feed tank through the barrels, both valves on the latter being open. The test was then started by closing the valve on the lower barrel and recording the time. When the water reached the mark in the lower barrel, the valve on the upper barrel was closed (causing the water to collect in this barrel temporarily) and the time and temperature noted, after which this water was dropped to the feed tank and the lower valve closed again. This method was followed until the end of the test, and, as will be observed from the tables, a record was kept of the time required to fill each barrel.

No attempt was made to specially prepare any auxiliary for testing. All were periodically examined and repaired as found necessary, and thus kept in good condition. The tests were made as opportunity offered, and with the auxiliary doing the actual service work required aboard ship.

Typical indicator cards, taken during the different tests, are appended.

As the water used by the steam cylinder of the starboard auxiliary condenser enters into all tests previous to November 25, 1896, the test of that auxiliary is given first.

ENGINE ROOM AUXILIARIES.

Steam cylinder of starboard auxiliary condenser.—Test No. 3, November 9, 1896.

Cooling surface, square feet..... 680
Diameter of steam cylinder, inches..... 8
air and water cylinders, inches..... 10
piston rod (common), inches..... 1½
Stroke, full, inches..... 12
Average stroke during test, inches..... 10¾

Test began at 2·30 P. M.

Time.	Steam pressure. Boiler.	Steam pressure. Engine room.	Vacuum. Starboard engine room.	Vacuum. Port engine room.	Steam cylinder, aux. condenser. Counter.	Double strokes.	Mean pressure.	I.H.P.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.										*h. m. s.*	*h. m. s.*		
2·30	87	87	9	8	68,986	32.8	13.85	1.196	...	.....	.....	...	76
3·00	90	90	7½	8	69,969	32.8	13.78	1.190	...	.....	.....	...	76
3·30	90	90	8½	7¾	70,855	29.6	13.85	1.080	...	.....	.....	...	76
4·00	90	90	8½	8	71,901	34.9	14.07	1.293	1	3'51"45	1'21"45	88	76
4·30	91	91	9¼	10	72,859	31.9	14.66	1.231	...	.....	.....	...	76
5·00	94	94	9	10	73,934	35.8	14.50	1.367	...	.....	.....	...	76
5·30	91	91	9¼	9¾	74,888	31.8	13.80	1.156	2	5'11"20	1'19"35	84	76
6·00	90	90	9½	10	75,933	34.8	14.86	1.136	...	.....	.....	...	76
6·30	91	91	9¼	9	76,920	32.9	14.06	1.218	...	.....	.....	...	76
7·00	90	90	10	8	77,975	35.1	15.50	1.433	3	6'31"08	1'19"48	83	76
7·51	93	93	13	12	79,642	32.7	14.55	1.253	4	7'51"00	1'19"52	82	76
Average.....			...	...	.....	33.2	.....	1.232	...	.....	.....	84.2	...

Net weight of a barrel of water (temp. 84°) = 438.81 lbs.

Duration of test ..... 5 h. 21 m.
Total weight of water collected, pounds 1,755.24
per hour, pounds..... 328.07
per I.H.P., pounds..... 266.30

Center main circulating pump engine.—Simple, vertical, inverted, direct-acting, two-cylinder engine with slide valves.—Test No. 4, November 10, 1896.

Power of engine approximately that developed on official trial July 14, 1894.

Diameter of cylinders, inches..... 10
piston rods, inches..... 1¾
Stroke, inches..... 6

Test began at 4·50 P. M.

Time.	Steam pressure		Vacuum.		Circulating pump engine.					Steam cylinder, auxiliary condenser.				Condensed exhaust steam				Injection.
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Counter.	Revolutions.	Mean pressures. For'd cylinder.	Mean pressures. After cylinder.	I.H.P.	Counter.	Double strokes.	Mean pressure.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	
P. M.															*h. m. s.*	*h. m. s.*		
4·30	150	148	11	12	37,000	...	...	...	...	2,212	..	...	...	...	...	...	...	71
5·00	144	142	11	12½	42,160	172.0	22.75	23.96	18.829	3,350	37·9	15.31	1.528	...	...	...	...	71
5·30	142	140	12	12	47,280	170.7	21.83	23.18	18.006	4,403	35.1	14.95	1.382	1	5·08·20	18·20	88	71
														2	5·27·10	18·50	85	
6·00	135	133	12½	12	52,340	168.6	22.78	22.70	18.010	5,355	31·7	15.45	1.290	3	5·46·25	19·15	86	71
6·30	144	142	13	14	57,330	166.3	22.05	22.75	17.460	6,359	33·4	15.85	1.394	4	6·04·55	18·30	85	71
														5	6·24·25	19·30	85	
7·00	152	150	14	13	62,640	177.0	25.57	26.00	21.392	7,370	33·7	16.10	1.429	6	6·43·15	18·50	84	71
7·30	145	143	14	13	67,840	173.3	23.50	23.43	19.060	8,353	32.8	15.55	1.343	7	7·00·55	17·40	85	71
														8	7·19·25	18·30	87	
8·00	142	140	14	13	73,030	173.0	23.48	24.25	19.352	9,339	32.9	15.00	1.299	9	7·38·15	18·50	85	71
														10	7·57·05	18·50	86	
Average..			...	...	...	171.6	...	...	18.873	...	33·9	...	1.381	...	...	...	85.6	...

Net weight of a barrel of water (temp. 86°) = 438.67 lbs.

Duration of test	3 h. 7 m. 5 s.
Total weight of water collected, pounds	4,386.7
per hour, pounds	1,406.9
per hour used by steam cylinder of auxiliary condenser (1.381 × 266.3, test No. 3), pounds	367.76
Weight of water per hour used by circulating pump engine, pounds	1,039.14
per I.H.P., lbs...	55.06

It will be seen, from an examination of indicator card No. 5 taken during this test, that the slide valves were designed to give very little cushioning and a late cut-off. To determine the resultant saving from an earlier cut-off and closing of exhaust, the valve to the forward cylinder was altered by the addition of $\frac{3}{16}$ inch outside and $\frac{1}{2}$ inch inside lap, and by increasing the angular advance of the eccentric 14 degrees. Test No. 5 was then made with this cylinder doing all the work and dragging the after piston and connections. Without altering the amount of injection opening, or any of the valves on the condenser, a comparative test of the after cylinder (Test No. 6) was made, the throttle and exhaust valves on the forward cylin-

der being closed, so that the after cylinder alone did work. The power developed in each test, as shown in the appropriate columns of I.H.P., was practically the same.

Before beginning these tests, great care was taken to insure both pistons and valves being steam tight, and the indicator motion to each cylinder was examined and proved.

An inspection of the indicator card (Card No. 6) produced by the forward cylinder, after the change in the valve, discloses an anomaly in the compression line which is not readily explained. The reverse compression curve there shown disappears gradually as the vacuum increases, and is entirely gone with a vacuum of 25 inches, as shown by Card No. 7.

Center main circulating pump engine; forward cylinder only doing work.—Test No. 5, March 3, 1897.

Test began at 2·47 P. M.

	Steam pressure.		Vacuum.		Circulating pump engine (forward cylinder).				Condensed exhaust steam.				
Time.	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Counter.	Revolutions.	Mean pressure.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.										*h. m. s.*	*h. m. s.*		
3'00	77	72	12	12	65,360	.....	.....	.....	...	.....	.....	...	64
3'30	78	76	12	12½	68,010	88.3	18.20	3.766	...	.....	.....	...	64
4'00	80	79	12	13	70,710	90.0	18.87	3.980	...	.....	.....	...	64
4'30	79	77	12	11	73,340	87.7	20.90	4.296	1	4'13'00	1'26'00	80	64
5'00	82	80	12	12	75,970	87.7	19.40	3.987	...	.....	.....	...	64
5'30	85	83	11½	12	78,860	96.3	19.90	4.491	2	5'36'30	1'23'30	80	64
Average.....			...	...	.....	90.0	.....	4.104	...	.....	.....	80	...

Net weight of a barrel of water (temp. 80°) = 439.09 pounds.

Duration of test	2 h. 49 m. 30 s.
Total weight of water collected, pounds	878.18
per hour, pounds	310.86
per I.H.P., pounds	75.74

Center main circulating pump engine; after cylinder only doing work.—Test No. 6, March 3, 1897.

Test began at 5·53 P. M.

Time.	Steam pressure.		Vacuum.		Circulating pump engine (after cylinder).				Condensed exhaust steam.				
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Counter.	Revolutions.	Mean pressure.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.										*h. m. s.*	*h. m. s.*		
6·00	81	78	16	13½	81,950	.....	.....	.....	...	.....	.....	...	64
6·30	79	76	18	18	84,520	85.7	23.00	4.619	...	.....	.....	...	64
7·00	83	81	18	18	87,290	92.3	19.40	4.196	1	6 57·00	1·04·00	78	64
7·30	84	82	18	18	90,100	91.7	17.40	3.821	...	.....	.....	...	64
8·00	86	84	18	18	92,690	86.3	17.40	3.519	2	8·04·00	1·07·00	78	64
Average.....			...	...	.....	89.5	.....	4.039	...	.....	.....	78	64

Net weight of a barrel of water (temp. 78°) = 439.21 lbs.

Duration of test	2 h. 11 m.
Total weight of water collected, pounds	878 42
per hour, pounds	402.33
per I.H.P., pounds	99 61
Saving in steam by alterations to valve (test No. 5), per cent	23 96

Starboard main circulating pump engine.—Test No. 7, at sea, December 4, 1896. Size, same as given in test No. 4. Wing engines in operation; revolutions per minute of starboard main engine, 53; I.H.P., 604.

Test began at 12 55 P. M.

Time.	Steam pressure.		Vacuum.			Circulating pump engine.					Condensed exhaust steam.				
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Center engine room.	Counter.	Revolutions.	Mean pressures. Forw'd cylinder.	Mean pressures. After cylinder.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.												*h. m. s.*	*h. m. s.*		
1·00	152	142	17½	15	12	27,770	...	...	...	..	...	.....	.....	...	68
1·30	152	142	15	14½	13½	30,230	82.0	...	...	...	...	.....	.....	...	68
2·00	158	148	15	14½	14	32,630	80.0	2.78	7.62	1.950	...	.....	.....	...	68
2·30	153	144	18	15	14	35,100	82.3	...	...	...	...	.....	.....	...	68
3·00	148	137	15	14¼	14	37,560	82.0	2.95	7.30	1.970	1	2·42·30	1·47·30	87	69
3·30	158	150	14½	14½	14	40,040	82.7	...	...	...	...	.....	.....	...	70
4·00	156	145	14	15	14½	42,530	83.0	2.95	8.00	2.130	...	.....	.....	...	70
4·30	157	150	12	15	13½	45,000	82.3	...	...	...	2	4·23·20	1·40·50	87	70
Average.....			...	...	...	.....	82.0	...	...	2.017	...	.....	.....	87	...

Net weight of a barrel of water (temp. 87°) = 438.6 lbs.

During this test, the auxiliary exhaust line was divided, by closing valves B and C, plate 1, into three sections. In the center engine room compartment, the exhaust from the auxiliaries in use was thrown into the main condenser there.

Duration of test	3 h. 28 m. 20 s.
Total weight of water collected, pounds	877.20
per hour, pounds	252.63
per I.H.P., pounds	125.28

Starboard main air pump engine.—Blake, vertical, two-cylinder engine. Test No. 8 (see p. 19), at sea, December 4, 1896.

Diameter of steam cylinders (2), inches	16
pump cylinders (2), inches	31½
piston rods, inches	3
pump rods, inches	5
Stroke, inches	21

This test was made under the same conditions, and with the main engine developing the power given in test No. 7.

As the starboard circulating pump engine exhausted only into the auxiliary exhaust line, the condensed exhaust steam collected included also the steam used by that auxiliary. The piping to the three main air pumps, however, was arranged so that the exhaust could either be sent direct to its own main condenser, or thrown into the auxiliary exhaust line.

Center main air pump engine.—Size, same as given in test No. 8. Test No. 9 (see p. 20), November 11, 1896.

In this test the center main propelling engine was not in operation, the air pump being loaded by opening the salt feed, thus admitting sea water to the main condenser. After being delivered into the feed tank by the air pump, the sea water was run into the bilges and finally pumped overboard by a port engine room pump.

It was impossible in this way to approach even approximately the power developed by the air pump under ordinary working conditions, as was at first the intention, because the slightest opening of the salt feed produced an abnormally large load. This was caused by the size, 2 inches, of the salt feed pipe, the head, 4 feet, and the vacuum within the condenser. During this test the average power developed by the air pump, with the salt feed valve just unseated, was about three times that on the official trial of the *Minneapolis* with the center engine indicating 7,219 H.P.

TEST No. 8 OF STARBOARD MAIN AIR PUMP ENGINE, DECEMBER 4, 1896.

Passage between Mersina, Asia Minor, and Jaffa, Palestine.

Test began at 4'54 P. M. Wing engines and two main boilers in use. I.H.P. of starboard engine, 604; revolutions, 53.

Time.	Steam pressure.		Vacuum.			Air pump engine.								Circulating pump engine.					Condensed exhaust steam.				
									Mean pressures.							Mean pressures.							
									Outboard cylinder.		Inboard cylinder.		I.H.P.					I.H.P.					
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Center engine room.	Counter.	Double strokes.	Vacuum, main condenser.	Top.	Bottom.	Top.	Bottom.		Counter.	Revolutions.	Forward cylinder.	After cylinder.		Number of Barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.																				*h. m. s.*	*m. s.*		
5'00	150	139	19	12½	14	2,377	...	25	...	...	...	...	...	47,650	...	...	...	...	...	...	...	...	69
5'30	149	138	19	14	14	2,888	17.03	25	...	...	...	...	...	50,410	92.0	...	...	...	1	5'11'40	17'40	98	69
																			2	5'29'05	17'25	94	
6'00	145	135	14	14	14	3,367	15.97	25	1.5	16.12	1.25	17.75	6.006	52,990	86.0	2.40	7.93	2.082	3	5'47'00	17'55	95	69
6'30	147	136	15	14	15	3,834	15.57	25	...	...	...	...	...	55,550	85.3	...	...	...	4	6'04'45	17'45	99	69
																			5	6'23'05	18'20	100	
7'00	153	141	14	14	13	4,336	16.73	25	6.37	15.12	1.00	17.12	6.851	58,180	87.7	2.25	9.25	2.364	6	6'41'10	18'05	99	69
																			7	6'58'40	17'30	99	
7'30	148	137	13	14	14	4,853	17.23	25	...	...	...	...	...	60,830	88.3	...	...	...	8	7'16'15	17'35	99	69
8'00	144	135	13	14	14	5,367	17.13	25	4.12	15.07	1.00	18.12	6.772	63,470	88.0	...	...	...	9	7'34'25	18'10	98	69
																			10	7'52'10	17'45	97	
Average.....			...	...	...	...	16.6	...	...	...	...	...	6.543	...	87.9	...	...	2.223	...	...	...	97.8	...

Net weight of a barrel of water temp. (98°) = 437.76.

Duration of test	2 h. 58 m. 10 s.
Total weight of water collected, pounds	4,377.6
per hour, pounds	1,474.2
per hour used by steam cylinders of circulating pump (2.223 × 125.28, test No. 7), pounds,	278.5
Weight of water per hour used by air pump engine, pounds	1,195.7
per I.H.P., pounds	182.74

TEST No. 9 OF CENTER MAIN AIR PUMP ENGINE, NOVEMBER 11, 1896.

Test began at 3·02 P. M. Ship in port. Pumps loaded by admitting sea water to the condenser through salt feed opening.

Time.	Steam pressure.		Vacuum.		Air pump engine.								* Steam cyl'r, aux. condenser.		Condensed exhaust steam.				
								Mean pressures.											
								Outboard cylinder.		Inboard cylinder.		I.H.P.							
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Counter.	Double strokes.	Vacuum, main condensers.	Top.	Bottom.	Top.	Bottom.		Counter.	Double strokes.	Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.																*h. m. s.*	*m. s.*		
3·00	110	107	14	13	2,960	...	23½	21.75	56.75	20.50	54.50	23.239	490	...	...	...	...	...	70
3·30	114	112	15	14	3,397	14.57	24	23.50	59.50	23.50	57.50	24.839	1,500	33.7	1	3·13·25	11·25	96	70
															2	3·25·05	11·40	98	
4·00	118	116	14½	14	3,850	15.10	24	22.50	61.00	21.75	56.75	25.417	2,490	33.0	3	3·36·40	11·35	99	70
															4	3·48·35	11·55	99	
															5	4·00·20	11·45	100	
4·30	119	117	14½	14	4,313	15.41	23	22.75	58.75	21.50	56.00	25.463	3,474	32.8	6	4·11·30	11·10	102	70
															7	4·22·34	11·04	102	
															8	4·33·50	11·16	102	
5·00	116	114	15	14½	4,765	15.07	22½	24.00	58.50	20.60	54.00	24.607	4,400	31.2	9	4·45·52	12.02	102	70
															10	4·57·40	11·48	102	
5·30	113	111	15	15	5,226	15.37	22½	23.50	57.50	21.50	56.25	25.360	5,464	35.2	11	5·08·45	11·05	101	70
															12	5·20·10	11·25	101	
															13	5·31·45	11·35	102	
6·00	121	119	15	15	5,694	15.60	22½	25.60	60.00	24.00	58.40	27.347	6,483	34.0	14	5·43·20	11·35	102	70
															15	5·54·05	10·45	102	
															16	6·04·42	10·37	103	
Average...	...	...	...	...	...	15.2	...	...	...	...	...	25.181	...	33.3	...	...	...	100.8	...

* Not indicated.

Net weight of a barrel of water (temp. 101°) = 437.52 pounds.

Duration of test..... 3 h. 2 m. 42 s.
Total weight of water collected, pounds..... 7,000.3
per hour, pounds..... 2,298.9
used by steam cylinder of starboard auxiliary condenser per hour (test No. 3), pounds..... 329
Weight of water used by air pump engine per hour, pounds..... 1,969.9
per I.H.P., pounds..... 78.23

Starboard engine room water service pump on fire main for flushing purposes: Blake, vertical, duplex.—Test No. 10, February 4, 1897. Speed of pump regulated to keep the "head" well flushed.

Diameter of steam cylinders, inches..... 7½
water cylinders, inches..... 4½
piston rods, inches..... 1 1/16
Stroke, full, inches..... 10
Average stroke during test, outboard cylinder, inches..... 7½
inboard cylinder, inches..... 7½

Test began at 4·57 P. M.

Time.	Steam pressure.		Vacuum.		Main engine water service pump.					Condensed exhaust steam.				
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Counter.	Double strokes.	Mean pressures. Outbd. cylinder.	Mean pressures. Inbd. cylinder.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.											*h. m. s.*	*h. m. s.*		
5·00	76	73	12	16	86	...	...	...	...	.....	.....	.....	...	66
5·30	82	80	12	16	1,167	36.0	8.25	7.10	.997	.....	.....	.....	...	66
6·00	102	99	12½	12½	2,437	42.3	...	...	...	.....	.....	.....	...	66
6·30	108	106	12½	14	3,732	43.2	...	...	...	.....	.....	.....	...	66
7·00	110	107	12	12½	4,971	41.3	...	...	...	1	6·54·20	1·57·20	84	66
7·30	95	92	9½	6½	6,123	38.4	7.75	7.95	1.082	.....	.....	.....	...	66
8·00	91	88	9	10	7,465	43.7	...	...	...	*1.4476	7·56·00	.....	84	66
Average.....			...	...	...	40.9	...	...	1.039	.....	.....	.....	84	...

Net weight of a barrel of water (temp. 84°) = 438.81 pounds.

*Test was stopped after collecting one barrel and 23½ gallons (= .4476 of a barrel) of the second barrel.

Duration of test..... 2 h. 59 m.
Total weight of water collected, pounds..... 635.23
per hour, pounds..... 212.92
per I.H.P., pounds..... 204.95

Center engine room fire and feed pump on fire main for flushing purposes: Blake, horizontal, duplex.—Test No. 11, December 2, 1896. Speed of pump regulated to keep the "head" well flushed.

Diameter of steam cylinders, inches..... 12
water cylinders, inches..... 8½
piston rods, inches..... 1 7/16
Stroke, full, inches..... 12
Average stroke during test, mean for both cylinders..... 10¾

Weight of water used by air pump engine per hour, pounds..... 1,969.9
per I.H.P., pounds..... 78.23

Test began at 4·28 P. M.

Time.	Steam pressure. Boiler.	Steam pressure. Engine room.	Vacuum. Starboard engine room.	Vacuum. Port engine room.	Fire and feed pump. Counter.	Double strokes.	Delivery pressure of pump.	Mean pressures. Outbd. cylinder.	Mean pressures. Inbd. cylinder.	I.H.P.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P. M.							*Pounds pr. sq. in.*					*h. m. s.*	*h. m. s.*		
4·30	105	101	17	15	2,521	...	16½	...	...	...	...	.....	.....	...	67
5·00	104	100	14¾	15	2,886	12 2	16½	4.8	5·3	·7599	...	.....	.....	...	67
5·30	104	100	15	15	3,255	12.3	16½	...	...	...	...	.....	.....	...	67
6·00	99	95	12	13	3,638	12.8	16½	4.8	5.67	.8103	...	.....	.....	...	67
6·30	100	99	12	11	4,000	12.1	16½	...	...	...	1	6·14·45	1·46·45	76	67
7·00	105	102	13	13	4,401	13.4	16½	...	...	...	...	.....	.....	...	67
7·30	105	102	13	14	4,806	13.4	16½	...	...	...	...	.....	.....	...	67
8·00	102	98	12½	13½	5,206	13.3	16½	...	...	...	2	7·58 45	1·44 00	74	67
Average.....			...	...	...	12.7	.....	...	...	.7851	...	.....	.....	75	...

Net weight of a barrel of water (temp. 75°) = 439.4 pounds.

Duration of test..... 3 h. 30 m. 45 s.
Total weight of water collected, pounds..... 878 8
per hour, pounds..... 250.19
per I.H.P., pounds 318.68

Center engine room fire and feed pump on fire main for washing decks: Size, same as given in Test No. 11.—Test No. 12, December 3, 1896. Pump made the full stroke of 12 inches during test.

Test began at 5·37 A. M.

Time.	Steam pressure. Boiler.	Steam pressure. Engine room.	Vacuum. Starboard engine room.	Vacuum. Port engine room.	Fire and feed pump. Counter.	Double strokes.	Delivery pressure of pump.	Mean pressures. Outbd. cylinder.	Mean pressures. Inbd. cylinder.	I.H.P.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
A. M.							*Pounds pr sq in.*					*h. m. s.*	*m. s.*		
5·45	82	82	19	18	5,836	...	30	...	...	...	...	.....	...	...	65
6·15	91	89	15	14½	6,970	37.8	34	13.49	14.51	7.202	1	6·04·00	27·00	77	65
6·45	100	98	14	13½	8,110	38.0	35	...	...	...	2	6·30·10	26·10	77	65
7·15	92	89	16	16	9,195	36.2	28	10.92	11.80	5.622	3 4	6·54·45 7·22 30	24·35 27·45	78 78	65
Average.....			...	...	...	37·3	.....	...	...	6.412	...	.....	...	77·5	...

Net weight of a barrel of water (temp. 77½°) = 439.24 pounds.

Duration of test..... 1 h. 45 m. 30 s.
Total weight of water collected, pounds..... 1,756.96
per hour, pounds..... 999.23
per I.H.P. pounds..... 155.84

Center engine room fire and bilge pump on bilges: Blake, vertical, duplex.—Test No. 13, February 1, 1897.

In this test, sea water was allowed to circulate by gravity through the different bearings, although the main engine was not in operation. The amount of water thus flowing into the bilges, and pumped overboard by the pump, was approximately that with the center engine in regular use at ordinary cruising speeds.

Diameter of steam cylinders, inches..... 14
water cylinders, inches..... 9
piston rods, inches..... 2
Stroke, full, inches..... 12
Average stroke during test, outboard cylinder, inches..... $11\frac{1}{8}$
inboard cylinder, inches..... $11\frac{3}{8}$

Test began at 6·02 P. M.

Time.	Steam pressure.		Vacuum.		Fire and bilge pump.					Condensed exhaust steam.				Injection.
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Counter.	Double strokes.	Mean pressures. Outbd. cylinder.	Mean pressures. Inbd. cylinder.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	
P.M.											*h. m. s.*	*h. m. s.*		
6·00	110	106	12	17	609	...	...	...	...	...	.....	.....	...	66
6·30	104	100	15	16½	1,364	25.2	...	...	...	...	.....	.....	...	66
7·00	107	103	15¼	14	2,368	33.5	6.97	4.92	3.016	...	.....	.....	...	66
7·30	97	93	13	13	3,146	25.9	...	...	...	1	7'01"00	59"00	76	66
8·00	100	96	14	15	3,934	26.3	4.95	3.95	2.022	2	8'04"30	1'03"30	74	66
Average.....			...	...	...	27.7	...	...	2.519	...	.....	.....	75	...

Net weight of a barrel of water (temp. 75°) = 439.4 pounds.

Duration of test..... 2 h. 2 m. 30 s.
Total weight of water collected, pounds..... 878.8
per hour, pounds..... 430.43
per I.H.P., pounds..... 170.87

FIRE ROOM AUXILIARIES.

Main fire room feed pump: Blake, vertical, duplex.—Test No. 14, at sea, December 24, 1896.

Diameter of steam cylinders, inches	12
water cylinders, inches	7½
piston rods, inches	1⅝
Stroke, full, inches	12
Average stroke during test, outboard cylinder, inches	11½
inboard cylinder, inches	8¾

In this test, the feed pump supplied two main boilers which furnished steam, through the auxiliary steam line, for all machinery in use; an attempt was made to maintain the water in the boilers at a constant level.

Valves in the auxiliary exhaust line were arranged as explained in test No. 7, and it was necessary, for the reason mentioned in test No. 8, to include, in the condensed exhaust steam collected from the feed pump, the exhaust steam also from the starboard circulating pump engine.

During the above test the main engines, port and starboard, running at the revolutions and under the same conditions recorded in Table I, developed 1,276 I.H.P. An estimate, based on the preceding tests of the steam used per hour by all machinery in operation, and, consequently, the amount of water which the feed pump had to deliver into the boilers in that time so as to preserve the water level at a constant height, is as follows.

	Test No.	Total lbs. of steam per hour.
Wing main engines	1	27,098.4
air pumps	8	2,391.4
circulating pumps	7 & 14	222.4
Steam cylinders port and starboard auxiliary condensers	3	656.1
Port fire and feed pumps (flushing)	11	250.1
bilge pump	13	430.4
Center engine air pump (estimated)	...	500
circulating pump	7 & 14	111.2
bilge pump (on starboard engine room bilges)	13	430.4
Steering engine (estimated)	...	450
Main feed pump	14	806.9
Dynamo	...	2,015
Condensation in auxiliary steam line, (estimated)	...	300

Test began at 3'22 P. M.

TEST No. 14.—MAIN FIRE ROOM FEED PUMP.

Time.	Steam pressure		Vacuum.			Main feed pump.						Starboard circulating pump engine.			Condensed exhaust steam.				Injection.
	Boiler.	Engine room.	Starb'd engine room.	Port engine room.	Center engine room.	Counter.	Double strokes.	Delivery pressure of pump.	Mean pressures. Outboard cylinder.	Mean pressures. Inboard cylinder.	I.H.P.	Counter.	Revolutions.	I.H.P.	Number of barrels.	Time full.	Time filling.	Temperature.	
P. M.								*Pounds per sq in.*	Not indicated. Assumed same as inboard cylinder.							*h. m. s.*	*h. m. s.*		
2'00	146	133	12	15	13	772	...	...		...	...	288,940	...	...	...	...	...	...	66
2'30	157	145	18	14	15	1,139	12.23	172		72.00	9.994	290,810	62.3	...	...	...	...	...	66
3'00	151	140	14	14	14	1,513	12.47	162		...	...	292,480	55.7	...	...	...	...	...	66
3'30	164	152	13	14	14	1,847	11.13	172		74.00	9.348	294,480	66.7	...	...	...	...	...	66
4'00	164	152	15	15	14	2,188	11.37	172		...	...	296,540	68.7	...	1	3'47'35	25'35	86	66
4'30	145	135	15	13	14	2,538	11.67	160		68.50	9.072	298,550	67.0	...	2	4'14'15	26'40	86	66
5'00	152	142	13	12	14	2,814	9.20	165		...	...	300,580	67.7	...	3	4'41'30	27'15	86	67
5'30	138	126	16	13	14	3,086	9.07	150		67.00	6.898	302,490	63.7	.8876	4 5	5'13'15 5'45'20	31'45 32'05	86 86	67
	Average.....		...	...	...	...	11.02	...	...	...	8.828	...	64.5	.8876	...	...	...	86	...

Net weight of a barrel of water (temp. 86°) = 438.67 pounds.

Duration of test	2 h. 23 m. 20 s.
Total weight of water collected, pounds	2,193.35
per hour, pounds	918.14
Weight of water per hour used by steam cylinders of circulating pump (.8876 × 125.28, test No. 7), pounds	111.20
feed pump, pounds	806.94
per I.H.P., pounds	91.41

	Test No.	Total lbs. of steam per hour.
Condensation in part of main steam line in use (estimated).....	...	125
from main engine jackets (estimated).....	...	750
Galley coppers, sick bay heaters, baths, &c.....	...	198
Loss of feed water (leakage of piping, valves, etc.) page 10.....	...	764.7
Total steam used per hour.....	...	37,500
Displacement of pump water pistons per hour (mean stroke, 10 inches), cubic feet.....	...	664.81
Feed water (temperature 80°) per hour, corresponding to pump displacement, pounds.....	...	41,372
Water actually delivered per stroke to displacement of pump pistons per stroke, per cent.....	...	90.6

Main fire room feed pump: Size, same as given in test No. 14.—Test No. 15, February 18, 1897.

Average stroke during test, outboard cylinder, inches..... 9½
inboard cylinder, inches..... 12

The usual port auxiliary machinery was in operation during this test, and water in the boiler under steam was maintained by the feed pump at a constant level in the gauge glass.

Test began at 4·40 P. M.

Time.	Steam pressure. Boiler.	Steam pressure. Engine room.	Vacuum. Starboard engine room.	Vacuum. Port engine room.	Main feed pump. Counter.	Double strokes.	Delivery pressure of pump, in pounds per square inch.	Mean pressures. Outbd. cylinder.	Mean pressures. Inbd. cylinder.	I.H.P.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
P.M.												*h. m. s.*	*h. m. s.*		
5·00	117	115	11	11½	256	...	128	Not indicated. Assumed same as inboard cylinder.	...	...	...	.....	.....	...	62
5·30	119	117	11	10½	337	2.70	131		50.88	1.676	...	.....	.....	...	62
6·00	117	114	11	11	413	2.53	130		...	...	...	.....	.....	...	62
6·30	120	117	11½	11	476	2.10	134		51.50	1.320	1	6·00·10	1·20·10	73	62
7.00	118	114	11	11	583	3.57	130		...	...	2	6·59·25	59·15	74	62
7.30	119	116	11	11	666	2.77	132		51.00	1.724	...	....	.....	...	62
8.00	117	114	11	10½	726	2.00	129		...	...	3	8·07 00	1·07·35	74	62
Average	...	...	...		...	2.61	...	...	...	1.573	...	.....	.....	73·7	...

Net weight of a barrel of water (temp. 74°) = 439.3 pounds.

Duration of test..... 3 h. 27 m.
Total weight of water collected, pounds..... 1,317.9
per hour, pounds..... 382.
per I.H.P., pounds..... 242.85

Starboard forced draft blower engine in No. 1 fire room: Sturtevant, two-cylinder, simple, double-acting engine, with cranks at 180°. One piston valve, without packing rings, controls the admission and emission of steam to both cylinders.—Test No. 16, March 5, 1897.

Diameter of cylinders, inches	5
piston rods, inches	1⅛
Stroke, inches	4
Diameter of fan, inches	60
piston valve, inches	2½
Travel of piston valve, inches	2¼

The forced draft system is of the closed fire room type. Fires were not lighted in the two forward boilers (see plate I), but the fire room was closed air tight, the furnace ash pan doors put in place, and leakage of air governed so as to produce the pressure shown in the table.

[9] Test began at 5·47 P. M.

Time.	Steam pressure.		Vacuum.		Blower engine.			Air pressure in fire room (ins. of water).	Condensed exhaust steam.				Injection.
	Boiler.	Engine room.	Starboard engine room.	Port engine room.	Revolutions.	Mean pressure (each cylinder).	I.H.P.		Number of barrels.	Time full.	Time filling.	Temperature.	
P. M.										*h. m. s.*	*m. s.*		
6·00	130	125	15½	14½	602	36.75	17.11	·7	...	.....	.....	...	62
6·30	123	118	15¼	15½	581	34.50	15.50	·7	1	6·06·40	19 40	70	62
									2	6.30·00	23·20	71	
7·00	123	118	15	15	603	...	.....	·7	3	6·50·30	20·30	71	62
									4	7·10·35	20·05	72	
Average.....			...	...	595.3	...	16.30	.....	...	.....	.....	71	...

Net weight of a barrel of water (temp. 71°) = 439.63 pounds.

Duration of test	1 h. 23 m. 35 s.
Total weight of water collected, pounds	1,758.52
per hour, pounds	1,262.39
per I.H.P., pounds	77.44

Starboard ash hoist engine in No. 5 fire room; Williamson, two-cylinder, simple, double-acting engine with slide valves.

Motion controlled and reversed by a change (piston) valve. Steam pistons grooved for water packing; engine shaft geared to drum carrying ash whip. Diameter of cylinders, 4½ inches; stroke, 4½ inches.—Test No. 17, February 25 and 26, 1897.

After turning steam on the hoist, and before the test began, several buckets were raised and lowered before recording data, in order to secure normal working conditions. The first test, February 25, extended over a period of 50 minutes, during which time 15 buckets of ashes were hoisted, the average gross weight of each being 180 pounds, and the net weight of ashes, 105 pounds. The lift was 37 feet 2 inches. Steam pressure in boiler, 120 pounds per gauge; vacuum in starboard auxiliary condenser, 11 inches.

The condensed exhaust steam collected amounted to 472.37 pounds, or 17.5 pounds per 100 gross weight raised.

On February 26, the test was repeated with the following results.

Duration of test, minutes	24
Number of buckets hoisted	17
Net weight of ashes raised, per bucket, pounds	122.4
Weight of ashes and bucket, pounds	195.3
Total gross weight hoisted, pounds	3,320.1
Steam pressure per gauge, in boilers, pounds	100
Vacuum starboard auxiliary condenser, inches	8
Condensed exhaust steam collected, pounds	309.38
Steam used per 100 pounds of gross weight hoisted, pounds	9.32

It will be observed that the work of hoisting was accomplished in 50 and 24 minutes respectively. The great difference between the results of these tests was no doubt due to leakage of steam from the pressure to the exhaust side of the change valve, which was grooved for water packing and which was not tight with the hoist at rest.

On account of the engine shaft gearing, it was necessary to use steam in lowering the empty bucket.

OTHER AUXILIARIES.

Dynamo engines.—The electric lighting plant consists of three 24-kilowatt generating sets constructed by the General Electric Company, Schenectady, N. Y. Each dynamo, which is

compound-wound of the multipolar type, is driven by a two-cylinder, simple, vertical, inverted engine, the crank shaft being coupled direct to the armature shaft, and the bed plate common to both engine and dynamo. The designed speed of each engine is 400 revolutions with 80 pounds of steam pressure, the maximum output being 300 amperes at 80 volts. There is, however, considerable reserve allowed for in the design, and the engines are capable of a much higher power than that necessary to produce the output mentioned.

The engine cranks are at an angle of 180 degrees, and one eccentric, working through a rock shaft, furnishes motion to drive both valves, one for each cylinder. These valves are of the piston type without packing rings, one supplying steam at its ends, and the other, in the middle. An automatic fly wheel governor regulates the angular advance of the eccentric, and tends to keep the speed constant with a variable load; the governor is set to obtain the required speed with the extreme opening of throttle, the voltage being kept constant by regulating a rheostat in the shunt field.

The valves are placed on the fronts of the cylinders, and the valve chests and cylinders are in one casting. The pistons, which are intended to be a neat fit to the cylinders, are flat, cored out with ribs $2\frac{7}{8}$ inches in depth, and have three circumferential grooves for water packing. An examination of the cylinders, pistons and valves, preliminary to testing, showed the following results.

No. 1 dynamo.—Both cylinders considerably eroded near middle of stroke, for about one-half the circumference, due to constant blowing of steam past the pistons; after cylinder in much worse condition than forward one; pistons a bad fit to cylinder bores. Forward valve a loose fit, after one fairly tight.

No. 2 dynamo.—Cylinder slightly pitted and rusty, except about one-third of circumference; after cylinder in better condition than forward one; pistons a closer fit than No. 1, but steam evidently blows past both pistons. Forward valve a fair fit, after valve loose and leaks.

No. 3 dynamo.—Cylinders in fair condition and pistons a good working fit. Forward valve loose and top bridge piece between ports rusty from leakage of steam; after valve a fairly good fit.

As before mentioned, one new set of pistons with spring rings was cast, and these substituted at different times, for the water-packed pistons in all three dynamo engines. To determine what saving resulted, a test was made of each engine before and after the change.

All tests were made with the dynamos doing the ordinary lighting of the ship. Usually one dynamo was sufficient for this, and in the absence of any special reason, it was the rule to change from one to another in regular order every twelve hours.

For convenience of comparison, all tests were divided into periods with respect to the load carried. Where tests were of short duration, it was customary to divide them into two periods; the first, generally with a light load, being completed, and the condensed exhaust water allowed to run directly through both barrels until the ammeter reading became steady with the additional circuits thrown in, before beginning to record data of the second period. This, however, was not always done, the record in some tests being continuous.

Reference has been made to the change of exhaust piping (shown in dotted lines on plate 1) to the steam cylinders of both auxiliary condensers, completed on November 25, 1897. Previous to that date, the condensed exhaust steam collected included the exhaust from the steam cylinder of the starboard auxiliary condenser, as well as the exhaust from the auxiliary under test; the alteration in piping made it possible to collect only the exhaust of the auxiliary being tested. As will be seen from the tables, dynamo tests were made before and after this change.

On account of the rough condition of the cylinder bores, the spring rings, when first fitted, were not perfectly steam tight, but a gradual improvement took place as the rings wore the cylinder walls smooth. This was apparent from an inspection of the cylinders, and also from an examination of the succeeding tests,

which indicate a saving, as a result of the alteration in the pistons, depending somewhat on the length of time the spring rings had been in use. Tests Nos. 18 and 20, of No. 1 dynamo engine, both of 24 hours duration, clearly exhibit the final saving to be expected. Both were made under as nearly identical conditions as it was possible to obtain, the output being that usually required for lighting the ship, and very closely the same in each case. In the first test, with water-packed pistons, the engine used on an average 2,695.6 pounds of steam per hour, while with new pistons and spring packing rings, the average steam consumption was reduced to 2,023.3 pounds per hour. The daily saving by the change, therefore, was 16,135.2 pounds of steam, or assuming one pound of coal to have evaporated $7\frac{3}{4}$ pounds of water at the boiler pressure used, 2,082 pounds of coal.

From an inspection of the different tables, it will be observed that the indicated horse power varied greatly at apparently the same output of the dynamos. Cards were taken with the utmost care, and, although this variation was noticed as the tests progressed, it was impossible to find any satisfactory explanation of the cause. The ammeter readings were checked approximately by counting the number of lights in use during some of the tests. This seemed to show that the readings for No. 1 and No. 3 dynamos were very nearly correct, but that for No. 2 was unreliable and probably inaccurate at all readings.

The important dimensions of each dynamo engine are as follows:

Diameter of cylinders, inches	$10\frac{1}{2}$
Stroke, inches	5
Diameter of piston rods, inches	$1\frac{1}{8}$
valves, inches	$5\frac{1}{4}$
Travel of piston valves, inches	$5\frac{3}{8}$

There is a reducing valve and a separator located in the dynamo room; the piping is so arranged that steam, before its admission to the cylinders of any of the three engines in use, passes through both.

TEST No. 18.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 1 DYNAMO ENGINE AND STEAM CYLINDER OF STARBOARD AUXILIARY CONDENSER. DYNAMO ENGINE PISTONS GROOVED FOR WATER PACKING.

Test began at 11 A. M. November 7, 1896. Duration of test, 24 hours.

	Time.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			Steam cylinder starboard auxiliary condenser.				No. 1 dynamo engine.					Reading of ammeter.	Reading of voltmeter.	Condensed exhaust steam.				Temperature injection.
		Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Reading of counter.	Double strokes.	Mean pressure.	I.H.P.	Revolutions.	Mean pressures. For'd cylinder.	Mean pressures. After cylinder.	Mean pressures. Total.	I.H.P.			Number of barrels.	Time full.	Time filling.	Temperature.	
—First Period.—Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in.—	A. M. 11'00	97	95	52	16	15	14	123,630	39.2	15.75	1.626	410	9.50	11.25	20.75	18 396	155	80.5	...	*h. m. s.* ...	*m. s.* ...	...	72
	11'30	92	91	50	16	12	14	124,805	39.2	...	...	400	...	...	...	...	160	81	1	11'09'15	9'15	101	73
																			2	17'35	8'20	101	
																			3	27'50	10'15	102	
	12'00	91	90	50	12	15	11	125,840	34.5	21.25	1.891	400	8.25	10.12	18.37	15.889	155	80.5	4	11'36'17	8'27	102	73
																			5	46'30	10'13	102	
	P. M.																		6	55 50	9'20	102	
	12'30	90	90	50	14	12	14	126,833	33.1	...	...	400	...	...	...	...	155	80.5	7	12'04'54	9'04	106	73
																			8	12'07	7'13	109	
																			9	21'05	8'58	108	
	1'00	94	94	52	14	13	14	127,935	36.7	14.62	1.382	410	9.00	11.05	20.05	17.775	155	80	10	12'30'10	9'05	102	73
																			11	40'28	10'18	104	
																			12	50'00	9'32	103	
																			13	59'55	9'55	102	
	1'30	98	98	52	14	12	14	128,990	35.1	...	...	410	...	...	...	...	155	80	14	1'09'25	9'30	103	73
																			15	19'10	9'45	103	
																			16	28'45	9'35	102	
	2'00	95	95	51	14	14	14	130,016	34.2	13.62	1.166	410	8.10	9.70	17.80	15.780	155	80	17	1'38'20	9'35	102	73
																			18	48'10	9'50	102	
																			19	57'50	9'10	103	
	2'30	94	94	51	14	14	14	130,938	30.7	...	...	410	...	...	...	...	155	80	20	2'07 25	9'35	103	73
																			21	16'45	9'20	103	
																			22	26 45	10'00	103	
	3'00	92	92	50	14	14	14	131,995	35.2	15.10	1.380	410	7.90	8.50	16.40	14.540	155	80	23	2'36'30	9'45	103	73
																			24	46'20	9'50	102	
																			25	56'15	9'55	102	
	3'30	95	95	51	14	11	14	133,020	34.2	...	...	410	...	...	...	...	155	80	26	3'06'15	10'00	102	73
																			27	16'00	9'45	102	
																			28	25'50	9'50	101	
	4'00	90	90	51	14	11	14	134,049	34.3	14.90	1.244	410	...	...	...	...	155	80	29	3'35'50	10'00	101	73
																			30	45'45	9'55	101	
																			31	55'50	10'05	101	
	Average.....	...	...	...	...	...	...	...	35.1	...	1.448	...	...	...	...	16.476	155.4	...	...	...	...	109'7	...

Second Period.—Added circuits 8, 9, 10 and 11 at 4 P. M.

4'05	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	32	4'04'05	8'15	103	
4'30	91	91	49	14	11	13	134,922	29.1	...	...	400	...	...	26.38	23.385	...	82				33	13'00	8'55	106	
																					34	28'30	7'30	107	73
5'00	88	88	48	13½	11	13	135,860	31.3	15.25	1.193	400	16.00	16.90	32.90	28.456	275	83				35	28'35	7'55	109	
																					36	4'36'00	8'01	109	
																					37	44'25	7'59	108	
5'30	94	94	48	14	12	13	136,706	28.2	...	...	410	16.05	16.68	32.93	29.194	285	82				38	53'25	9'00	110	74
																					39	5'01'08	7'43	111	
																					40	09'35	8'27	113	
6'00	90	90	48	12½	11½	13	137,756	35.0	16.03	1.359	410	15.87	15.75	31.62	28.032	285	82				41	15'50	6'15	114	
																					42	22'00	6'30	112	
																					43	5'29'35	7'15	112	
																					44	36'50	7'15	112	
6'30	87½	87	47	12½	11½	12	138,636	29.3	...	...	410	15.95	14.87	30.82	27.323	295	82				45	44'23	7'33	112	74
																					46	51'50	7'27	112	
																					47	59'31	7'41	112	
																					48	6'07'00	7'29	112	
																					49	14'25	7'25	112	
7'00	92	92	47	13	12	12	139,590	31.8	15.62	1.312	410	16.18	16.43	32.61	28.910	295	82				50	22'08	7'43	113	
																					51	29'36	7'28	112	
																					52	6'37'10	7'34	113	
																					53	45'32	8'22	113	74
																					54	52'53	7'21	113	
																					55	59'22	6'29	113	
7'30	81	81	47	12	11½	12	140,548	31.9	...	...	410	15.75	16.50	32.25	28.591	290	82				56	7'06'44	7'22	113	
																					57	14'18	7'34	113	75
																					58	21'40	7'22	113	
																					59	29'09	7'29	112	
8'00	95	95	47	13	12	12	141,539	33.0	15.50	1.388	410	13.20	17.50	30.70	27.217	285	82				60	7'36'31	7'22	113	
																					61	44'06	7'35	112	
																					62	52'35	8'29	113	
																					63	8'00'15	7'40	112	
8'30	100	100	49	13½	12¾	12½	142,588	34.9	...	...	410	13.95	12.43	26.38	23.387	272	82				64	07'50	7'35	112	
																					65	14'30	6'40	110	75
																					66	22'00	7'30	110	
																					67	29'50	7'50	109	
9'00	94	94	49	13¼	12¼	12½	143,210	37.4	18.30	1.614	410	12.50	15.15	27.65	24.513	255	84				68	8'37'35	7'45	109	
																					69	45'30	7'55	109	75
																					70	54'35	9'05	109	
																					71	9'02'30	7'55	109	
9'30	91	91	48	12½	12	12	144,601	29.7	...	...	410	13.06	15.85	28.91	25.630	250	83				72	10'45	8'15	109	
																					73	18'45	8'00	109	
																					74	26'50	8'05	110	
Average.....		...	...	...	...	...	...	32.0	...	1.373	...	...	...	...	26.780	276.1	...				...	...	...	110'9	...

Fitz
4'00 90 90 51 14 11 14 ... ... 35.1 ... 1.448 ... ... 16.476 155.4 ... 80 { 30 31 } 3'35'50 55'50 10'00 10'05 } 101 101 } 73
Average..... ... ...

TEST No. 18—*Continued.*

	Time.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			Steam cylinder, starboard auxiliary condenser.				No. 1 dynamo engine.							Condensed exhaust steam.				
													Mean pressures.										
		Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Reading of counter.	Double strokes.	Mean pressure.	I.H.P.	Revolutions.	For'd cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.	Reading of voltmeter.	Number of barrels.	Time full.	Time filling.	Temperature.	Temperature injection.
	P. M.																			*h. m. s.*	*m. s.*		
Third Period.	10'00	92	92	49	12	11½	11½	145,348	24.9	17.40	1.223	410	12.88	13.75	26.63	23.609	237	83.5	75	9'34'50	8'00	110	
																			76	43'00	8'10	110	75
																			77	51'10	8'10	111	
																			78	59 15	8'05	111	
	10'30	91	91	49	12¾	12	12½	146,202	28.5	...	...	410	11.00	10.76	21.76	19.291	217	81	79	10'07'15	8'00	111	
																			80	15'20	8'05	110	75
																			81	23'25	8'05	109	
																			82	10'31 55	8'30	108	
	11'00	90	90	49	14	12	13½	147,120	30.6	17.67	1.322	410	11.12	12.75	23.87	21.162	217	83	83	40'40	8'45	107	
																			84	49 15	8'35	107	75
																			85	57'15	8'00	108	
	Average.....	...	...	...	...	...	...	...	28.0	...	1.273	...	...	...	...	21.354	223.7		...	...	...	109.3	...
Period.																							
																			86	11'05'10	7'55	108	
																			87	13'00	7 50	109	
	11'30	94	94	49	13	12½	12½	147,906	26.2	...	...	410	...	...	...	...	212	82.5	88	21'05	8'05	111	75
																			89	29 55	8'50	108	
																			90	11'38'40	8'45	108	
	12'00	92	92	49	12½	12¼	12⅛	148,792	29.5	17.00	1.285	410	11.37	14.00	25.37	22.492	212	82	91	47'00	8'20	108	75
	Nov. 8																		92	55'45	8'45	108	
	A. M.																		93	12'04'30	8'45	108	
	12'30	92	92	50	12½	12	12	149,627	27.8	...	...	410	...	...	...	...	212	84	94	13 17	8'47	108	75
																			95	22'00	8 43	109	
																			96	12'30'35	8'35	109	
																			97	39'25	8'50	108	
	1'00	90	90	49	12	12	11½	150,472	28.1	17.00	1.200	410	10.50	12.62	23.12	20.497	200	80	98	48'30	9'05	108	75
																			99	57'15	8'45	107	

Fourth	1'30	85	85	49	11	11¾	11	151,238	25.5	...	...	410	...	...	...	800	80	100	1'06'10	8'55	107	75
																		101	15'10	9'00	108	
	2.00	90	90	50	11½	12	11	152,039	26.7	13.87	.975	410	10.90	10.18	21.08	18.688	200	102	24'05	8'55	108	
																		103	1'33'05	9'00	108	
																		104	47'00	8'55	109	75
	2'30	90	90	50	11½	12	11	152,837	26.6	...	...	410	...	...	...	...	195	105	50'55	9'00	108	
																		106	54'57	8'58	108	
																		107	2'38'55	8'58	108	
																		108	17'50	8'55	108	75
	3'00	87	87	49	11	12	11	153,605	25.6	15.43	1.036	405	11.18	13.85	24.43	21.399	200	109	20'50	9'00	108	
																		110	2'35'47	8'57	108	
																		111	44'45	8'58	108	
																		112	53'30	8'45	108	75
	3'30	87	87	50	11	12	11	154,367	25.4	...	...	405	...	...	...	...	200	113	3'02'25	8'55	109	
																		114	11'15	8'50	109	
																		115	20'10	8'55	109	
																		116	28'47	8'37	109	75
	4'00	95	95	51	12	12	11	155,209	28.1	15.08	1.135	410	10.50	13.38	23.88	21.171	200	117	3'37'30	8'43	109	
																		118	40'17	8'47	109	
																		119	54'55	8'38	109	
																		120	4'03'44	8'49	110	75
	4'30	93	93	50	12½	12½	12	156,086	29.2	...	...	410	...	...	...	...	195	121	12'39	8'55	106	
																		122	20'46	8'07	106	
																		123	29'50	9'04	106	
																		124	4'38'10	8'20	106	74
	5'00	95	94	50	13½	12½	12	156,993	30.2	15.70	1.232	410	9.80	14.00	23.50	20.833	200	125	49'15	10'05	106	
																		126	57'00	8'45	106	
	Average.....			...	...	...	...	...	27.4	...	1.144	...	...	...	...	20.847	202.2	...	...	...	...	107.9	...
Fifth Period.	5'30	94	94	49	12	13	12	157,876	29.4	...	...	405	...	...	...	...	235	127	5'06'39	9'39	107	74
																		128	15'10	8'31	108	
																		129	22'33	7'23	108	
																		130	5'31'05	8'32	109	
	6'00	94	93	48	11½	13	11	158,720	28.1	16.20	1.158	410	13.15	15.50	28.65	25.399	250	131	39'10	8'05	110	74
																		132	47'52	8'42	112	
																		133	55'45	7'53	113	
																		134	6'03'45	8'00	113	
																		135	11'45	8'00	113	
	6'30	93	92	48	11½	13½	11	159,493	25.9	...	...	410	...	...	...	245	81	136	19'50	8'05	113	74
																		137	27'50	8'00	113	
																		138	6'35'50	8'00	113	
																		139	43'50	8'00	113	
	7'00	95	94	50	12	10½	12	160,346	28.4	16.50	1.234	410	...	...	...	250	80	140	51'48	7'58	113	74
																		141	59'50	8'02	112	
	Average.....			...	...	...	...	...	27.9	...	1.193	...	...	...	...	25.399	245	...	...	...	...	111.3	...

TEST No. 18—*Continued.*

Time.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			Steam cylinder, starboard auxiliary condenser.				No. 1 Dynamo engine.					Reading of ammeter.	Reading of voltmeter.	Condensed exhaust steam.				Temperature injection.
	Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Reading of counter.	Double strokes.	Mean pressure.	I.H.P.	Revolutions.	Mean pressures. For'd cylinder.	After cylinder.	Total.	I.H.P.			Number of barrels.	Time full.	Time filling.	Temperature.	
A. M.																			*h. m. s.*	*m. s.*		
7'05	...	...	...	...	...	...	...	...	...	...	410	8.25	10.38	18.63	16.516	...	...					
7'30	94	93	50	12	8	12	161,196	28.4	...	...	410	...	...	...	...	170	82	142	7°08'20	8'30	108	
																		143	17'50	9'30	106	74
																		144	27'14	9'24	105	
8'00	91	91	50	11½	12⅝	12	162,106	30.3	16.02	1.194	410	8.93	11.62	20.55	18.218	165	81	145	7°36'30	9'16	105	
																		146	46'55	10'25	105	74
																		147	56'10	9'15	105	
8'30	91	91	50	13	12	13	162,892	26.2	...	...	410	...	...	...	...	170	82	148	8°05'25	9'15	104	
																		149	14'30	9'05	105	74
																		150	23'40	9'10	105	
9'00	90	90	50	13	11¾	13	163,754	28.7	16.00	1.222	410	8.90	8.25	17.55	15.204	170	82	151	8°33'00	9'20	105	
																		152	42'20	9'20	105	74
																		153	51'50	9'30	105	
9'30	93	93	51	13	12	12½	164,631	29.2	...	...	410	...	...	...	...	165	80	154	9°01'00	9'10	105	
																		155	10'15	9'15	105	74
																		156	19'20	9'05	105	
																		157	28'45	9'25	105	
10'00	89	89	51	12½	12	13	165,498	28.9	15.87	1.216	410	9.62	11.75	21.37	18.946	167	81.5	158	9°37'55	9'10	104	
																		159	47'10	9'15	104	74
																		160	56'30	9'20	105	
10'30	90	90	51	12¼	12	10½	166,314	27.2	...	...	410	...	...	...	...	165	80	161	10°05'40	9'10	105	
																		162	14'45	9'05	105	74
																		163	24'00	9'15	105	
11'00	92	92	51	11⅛	12	10½	167,160	28.2	15.47	1.149	410	9.00	10.95	19.95	17.687	165	80	164	10°33'20	9'20	105	
																		165	42'25	9'05	106	74
																		166	51'35	9'10	105	
																		167	11°00'50	9'15	105	
Average.....	...	...	...	...	...	...	...	28.4	...	1.195	...	...	...	...	17.314	167.1	...	...	...	...	105	...

Sixth Period. Threw out circuits 8, 9, 10 and 11 at 7 A. M.—

Average.....	...	...	...	...	...	28.4	...	1.195	...	...	...	...	17.314	167.1	...	...	...	...	105	...

SUMMARY OF TEST No. 18 OF No. 1 DYNAMO ENGINE, NOVEMBER 7 AND 8, 1896.

Period.	Date and hour.	Duration of period in hours.	Indicated horse power. Dynamo engine. Total of cards for period.	Indicated horse power. Dynamo engine. Average for period.	Indicated horse power. Steam cylinder starboard aux. condenser. Total of cards for period.	Indicated horse power. Steam cylinder starboard aux. condenser. Average for period.	Ampères. Total for period.	Ampères. Average for period.	Condensed exhaust steam. Number of barrels.	Average temperature.	Net weight of one barrel of water. Pounds.	Total weight collected in pounds.	Weight per hour. Pounds. Total.	* Used by steam cylinder of auxiliary condenser.	Used by dynamo engine.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.
1	November 7, 1896. 11 A. M. to 4 P. M.	5	82.380	16.476	8.689	1.448	1,710	155.4	31.505	103°	437.33	13,778	2,755.6	385.6	2,370.0	143.85	15.25
2	4 P. M. to 9·30 P. M.	5½	294.578	26.780	6 866	1.373	3,037	276.1	42.891	111°	436.44	18,719	3,403.5	365.6	3,037.9	113.44	11.00
3	9·30 P. M. to 11 P. M.	1½	64.062	21.354	2.545	1.273	671	223.7	10.952	109°	436.65	4,782	3,188.0	339.0	2,849.0	133.42	12.74
4	November 7 and 8. 11 P. M. to 5 A. M.	6	125.080	20.847	6.863	1.144	2,426	202.2	40.964	108°	436.77	17,892	2,982.	304.6	2,677.4	128.43	13.24
5	November 8. 5 A. M. to 7 A. M.	2	25.399	25.399	2.386	1.193	980	245	14.709	111°	436.44	6,419	3,209.7	317.7	2,892.0	113.86	11.80
6	7 A. M. to 11 A. M.	4	86.571	17.314	4.781	1.195	1,337	167 1	25.890	105°	437.15	11,318	2,829.5	318.2	2,511.3	145.04	15.03
"	Total.	...	678.07	...	32.13	...	10,161	...	166.911	...	...	72,908	...	...	...	...	...
"	Divisor.	...	31	...	25	...	49	...	...	...	...	24	...	...	...	...	...
Average for 24 hours.....		...	21.873	...	1.285	...	207.4	...	...	...	...	3,037.8	...	342.2	2,695.6	123.27	13.00

* Calculated from results obtained in test No. 3 . . . I.H.P. $\times$ 266.3 = steam used per hour.

Average steam per hour per I.H.P. for 24 hours = $\frac{3,037.8 - 342.2}{21.873} = 123.27$. Average steam per hour per ampère for 24 hours = $\frac{2,695.6}{207.4} = 13.00$.

TEST No. 19, JANUARY 4, 1897. COLLECTING CONDENSED EXHAUST STEAM FROM No. 1 DYNAMO ENGINE. NEW PISTONS WITH RINGS IN PLACE, HAVING BEEN IN USE ABOUT TEN DAYS.

Test began: First period, 1'43 P. M.; duration of test, 1 hour 15 minutes 40 seconds. Second period, 3'14 P. M.; duration, 1 hour 20 minutes 10 seconds.

	Time.	Steam pressure. (Gauge.) Boiler.	Engine room.	Dynamo room.	Vacuum. (Inches.) Starboard engine room.	Center engine room.	Dynamo room.	No. 1 Dynamo engine. Revolutions.	Mean pressures. Forward cylinder.	After cylinder.	Total.	I H.P.	Reading of ammeter.	Reading of voltmeter.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Weight per hour, pounds. Total.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.	Temperature injection.
First Period.*	P. M.															*h. m. s.*	*m. s.*					
	1'30	99	91	65	15½	15	11½	421	...	...	...	...	156	82	...	...	...	...	$\frac{438.14 \times 5 \times 3,600}{4,540} =$	$\frac{1,737.1}{19.598} =$	$\frac{1,737.1}{155} =$	69
	2'00	109	102	73	16	16	14½	425	7.81	14.12	21.93	20.144	156	82	1	1'57'55	14'55	97				69
	2'30	113	106	75	16½	16	15	426	...	...	...	...	156	80	2	2'12'45	14'50	94				69
															3	28'00	15'15	92				
	3'00	113	106	75	16½	15	15	425	7.62	13.12	20.74	19.052	152	79	4	2'43'10	15'10	92				69
															5	58'40	15'30	90				
	Average.....	...	...	...	...	...	...	...	...	...	...	19.598	155	...	...	...	...	...	93	1,737.1	88.64	11.21	...
Second Period.†	3'30	112	105	71	15	15½	13½	421	16.12	20.75	36.87	33.549	273	82	1	3'26'05	12'05	96	$\frac{437.7 \times 7 \times 3,600}{4,810} =$	$\frac{2,293.2}{33.601} =$	$\frac{2,293.2}{275\frac{1}{3}} =$	69
	4'00	109	102	70	15	14	10½	412	...	...	...	...	275	82	2	3'37'50	11'45	98				69
															3	49'40	11'50	98				
	4'30	92	85	66	13	13	11	418	16.75	20.50	37.25	33.654	278	82	4	4'00'35	10'55	98				69
															5	11'20	10'45	98				
															6	22'40	11'20	98				
															7	34'10	11'30	98				
	Average.....	...	...	...	...	...	...	...	...	...	...	33.601	275⅓	...	...	...	...	...	97.7	2,293.2	68.25	8.33	...

* First period. Circuits 1, 2, 3, 4, 5, 6, 7 and 8 and two motors cut in. . . Net weight of a barrel of water (temp. 93°) = 438.14 pounds.
† Second period. Added circuits 9, 10 and 11 at 3 P. M. . . . . Net weight of a barrel of water (temp. 98°) = 437.7 pounds.

TEST No. 20, MARCH 8 AND 9, 1897.—COLLECTING CONDENSED EXHAUST STEAM FROM

* First period. Circuits 1, 2, 3, 4, 5, 6, 7 and 8 and two motors cut in. . . Net weight of a barrel of water (temp. 93°) = 438.14 pounds.
† Second period. Added circuits 9, 10 and 11 at 3 P. M. . . . . Net weight of a barrel of water (temp. 98°) = 437.7 pounds.

TEST No. 20, MARCH 8 AND 9, 1897.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 1 DYNAMO ENGINE. NEW PISTONS WITH RINGS FITTED IN CYLINDERS.

Test began at 11 A. M. March 8. Duration of test, 24 hours.

Date and hour.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			No. 1 dynamo engine.							Condensed exhaust steam				Temperature injection.
								Mean pressures.										
	Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Revolutions.	For'd cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.	Reading of voltmeter.	Number of barrels.	Time full.	Time filling.	Temperature.	
March 8.															*h. m. s.*	*m. s.*		
A. M.																		
11'00	100	95	54	17	17	14½	419	11.62	14.00	25.62	23.202	159	81	...	...	...	...	66
11'30	100	95	53	17	17	14½	418	...	...	...	...	158	80	1	11'14'45	14'45	76	67
														2	29'30	14'45	75	
12'00	102	97	54	17½	17½	15	416	10.80	15.25	26.05	23.422	157	80	3	11'44'15	14'45	75	66
P. M.														4	58'45	14'30	76	
12'30	100	95	54	17	17½	15	417	...	...	...	...	156	80	5	12'13'30	14'35	76	66
														6	28'30	15'10	76	
1'00	100	95	54	17	17	14	412	10.90	13.75	23.75	21.149	157	80	7	12'43'30	15'00	76	66
														8	58'15	14'45	76	
1'30	100	95	53	16½	16½	14½	418	...	...	...	...	160	80	9	1'12'15	14'00	76	66
														10	25'10	12'55	76	
2'00	99	95	53	17	17	14½	414	11.00	14.68	25.68	22.979	160	80	11	1'38'50	13'40	76	65
														12	53'15	14'25	76	
2'30	103	97	54	17	17	14½	419	...	...	...	...	160	80	13	2'08'00	14'45	76	65
														14	22'05	14'05	77	
3'00	108	104	54	17	16½	15	418	9.75	14.18	23.93	21.619	160	80	15	2'35'30	13'25	77	65
														16	49'10	13'40	77	
3'30	106	101	54	17	16½	15	417	...	...	...	...	157	80	17	3'03'05	13'55	77	66
														18	17'10	14'05	76	
4'00	95	90	52	16½	17	14½	418	9.62	14.25	23.87	21.565	160	80	19	3'31'45	14'35	76	66
														20	45'45	14'00	76	
														21	59'45	14'00	77	
4'30	98	94	52	16½	16	14½	418	...	...	...	...	158	80	22	4'13'30	13'45	77	66
														23	27'20	13'50	77	
5'00	111	106	55	17	17	15	420	10.12	14.56	24.68	22.404	157½	79	24	4'41'10	13'50	77	66
														25	55'10	14'00	76	
Average.....	...	...	...	...	...	...	...	...	...	...	22.334	158.4	...	...	...	...	76.2	...

—First Period.—Circuits 1 to 8, and one motor cut in.—

TEST No. 20—*Continued*.

Date and hour.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			No. 1 Dynamo engine.					Reading of ammeter.	Reading of voltmeter.	Condensed exhaust steam.				Temperature injection.
								Mean pressures.			I.H.P.			Number of barrels.	Time full.	Time filling.	Temperature.	
	Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Revolutions.	For'd cylinder.	After cylinder.	Total.								
P. M.															*h. m. s.*	*m. s.*		
5'30	116	112	55	17	17	15	414	17.56	21.75	39.31	35.174	250	82½	26	5'09'20	14'10	76	65
														27	23'30	14'10	76	
6'00	105	100	50	17	17	14	412	20.75	21.87	42.62	37.952	265	81	28	5'35'40	12'10	76	
														29	46'45	11'05	78	66
														30	58'15	11'30	78	
6'30	105	100	50	17	17	14	419	21.12	21.75	42.87	38.823	285	82	31	6'09'30	11'15	80	
														32	20'35	11'05	80	64
7'00	113	108	50	17	17	14	416	21.25	21.93	43.18	38.824	287½	82	33	6 31'30	10'55	80	
														34	42'30	11'00	80	64
														35	53'20	10 50	80	
														36	7'04'10	10'50	80	
7'30	125	120	53	17	17	14½	414	21.12	22.12	43.24	38.692	294	82½	37	15'00	10'50	80	64
														38	25'50	10'50	80	
														39	7'36'40	10'50	80	
8'00	130	125	52	17	17	14½	413	21.00	22.00	43.00	38.384	290	81	40	47 30	10'50	80	64
														41	58'30	11'00	80	
8'30	115	110	52	17	17	14	415	19.75	21.50	41.25	37.000	285	82	42	8'09'30	11'00	80	65
														43	20'30	11'00	80	
														44	8'31'40	11'10	80	
9'00	110	105	52	17	17	14	414	19.06	19.37	38.43	34.387	262	84	45	42'50	11'10	80	64
														46	54'10	11'20	80	
														47	9'05'50	11 40	80	
9'30	107	102	52	17	17	14	417	17.50	19.00	36 50	32.897	243	83	48	17'30	11'40	80	64
														49	29'25	11'55	79	
10'00	108	103	52	17	17	14	417	17.00	18.00	35.00	31.546	233	82	50	9'41'25	12'00	79	64
														51	53'25	12'00	79	
Second Period. Added circuits 9, 10 and 11 at 5'30 P. M. Average.....	...	...	...	...	...	...	...	...	...	...	36.368	269.4	...	...	...	...	79.3	...

Third Period.	10·30	115	110	53	17	17	14½	419	15.62	17.50	33.12	29.993	212	81	52	10°05'25	12°00	79	64
															53	17'50	12'25	78	
	11·00	117	112	53	17	17	14½	412	15.50	16.87	32.37	28.825	210	81	54	10°30'20	12°30	78	64
															55	43'00	12'40	78	
															56	55'10	12'10	78	
	11·30	123	118	54	17	17	14½	414	...	...	...	...	205	81	57	11°07'40	12°30	78	64
															58	20'20	12'40	78	
	12·00	120	115	53	17	17	14½	413	14.25	16.37	30.62	27.333	202	80	59	11.33'00	12'40	77	64
	Mch. 9 A. M.														60	45'45	12'45	77	
															61	58'28	12'43	77	
	12·30	110	105	53	17	17	14½	414	...	...	...	...	202	80	62	12°11'25	12°57	77	64
															63	24'30	13'05	77	
	1·00	107	102	53	17	17	14½	414	14.37	15.00	29.37	26.280	190	80	64	12°37'41	13'11	77	64
															65	51'00	13'19	77	
	1·30	120	115	55	17	17	15	413	...	...	...	...	190	80	66	1°04'25	13'25	77	64
															67	17'40	13'15	76	
	2·00	115	110	54	17	17	15	412	14.50	15.50	30.00	26.714	187	80	68	1°30'45	13'05	76	64
															69	44'21	13'36	76	
															70	57'55	13'34	76	
	2·30	115	110	54	17	17	15	418	...	...	...	...	190	80	71	2°11'30	13'35	76	64
															72	24'55	13'25	76	
	3·00	117	112	54	17	17	15	412	14.75	15.75	30.50	27.160	185	80	73	2°38'26	13 31	76	64
															74	52'11	13'45	76	
	3·30	110	105	53	17	17	14½	412	...	...	...	...	190	80	75	3°05'43	13'32	76	64
															76	19'10	13'27	76	
	4·00	109	104	53	17	17	14½	414	14.25	16.00	30.25	27.068	195	80	77	3°32'52	13'42	76	65
															78	46'20	13 28	76	
															79	59'50	13'30	76	
	4·30	107	102	53	17	17	15	416	...	...	...	...	195	81	80	4°13'20	13'30	76	65
															81	26'50	13'30	76	
	5·00	109	104	53	17	17	15	416	15.25	17.37	32.62	29.329	200	81	82	4°40'20	13'30	76	64
															83	53'30	13'10	76	
	Average.....	...	...	...	...	...	...	...	...	...	...	27.838	196.6	...	...	..	...	76.7	...
Fourth Period.*	5·30	113	108	53	16	16	14	413	...	...	...	...	230	80	84	5°06'30	13'00	76	64
															85	19'10	12'40	76	
	6·00	100	95	50	15½	16	12½	415	18.75	19.12	37 87	33.968	235	80	86	5°31'40	12'30	76	64
															87	44'10	12'30	76	
															88	56'45	12'35	77	
	6·30	98	92	50	16	16	13	413	...	...	...	...	240	80	89	6°09'30	12'45	77	64
															90	19'15	9.45	78	
	7·00	99	94	50	16	16	13	413	18.75	19.31	38.06	33.974	240	80	91	6°30'45	11 30	78	64
															92	43'05	12'20	77	
															93	55'10	12 05	77	
	7·30	105	100	51	16	16	13½	413	...	...	...	...	228	82½	94	7°07'10	12'00	77	64
															95	19'00	11'50	77	
	Average.....	...	...	...	...	...	...	...	...	...	...	33.971	234.6	...	...	...	...	76.8	...

*Cut out motor circuit at 7·30 A. M.

TEST No. 20—*Continued.*

	Date and hour.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			No. 1 dynamo engine.							Condensed exhaust steam.				
									Mean pressures.										
		Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Revolutions.	For'd cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.	Reading of voltmeter.	Number of barrels.	Time full.	Time filling.	Temperature.	Temperature injection.
Fifth Period.*	A. M.															*h. m. s.*	*m. s.*		
	8.00	105	100	53	16	16	14	416	12.75	13.62	26.37	23.710	139	82	96	7.31.00	12.00	77	
															97	42.45	11.45	76	64
															98	57.30	14.45	76	
	8.30	90	85	53	16	16	14	414	...	...	...	...	147	81	99	8.13.30	16.00	75	
															100	28.30	15.00	75	64
	9.00	105	100	52	17	17	14½	415	11.75	14.75	26.50	23.770	162	82	101	8.42.54	14.24	75	
															102	57.09	14.15	76	64
	9.30	103	98	53	17	17	14½	413	...	...	...	...	160	81	103	9.11.14	14.05	75	
															104	25.34	14.20	75	64
	10.00	105	100	53	17	17	14½	415	11.37	14.62	25.99	23.312	158	81	105	9.39.34	14.00	75	
															106	53.44	14.10	75	64
	10.30	100	95	53	17	17	14½	413	...	...	...	...	156	81	107	10.08.04	14.20	75	
															108	23.09	15.05	75	64
	11.00	103	98	53	17	17	14½	415	11.37	14.56	25.93	23.258	155	79	109	10.37.39	14.30	75	
															110	52.04	14.25	75	64
															111	11.06.24	14.40	75	
	Average.....	...	...	...	...	...	...	...	...	...	...	23.512	153.9	...	...	...	...	75.3	...

*Cut out circuits 9, 10 and 11 at 7.46 A. M. Threw in motor circuit at 8.35 A. M.

SUMMARY OF TEST No. 20 OF No. 1 DYNAMO ENGINE, MARCH 8 AND 9, 1897.

Period.	Date and hour.	Duration of period in hours.	I.H.P. of Dynamo engine.		Ampères.		Condensed exhaust steam.						
											Weight per hour. Pounds.		
			Total of cards for period.	Average for period.	Total for period.	Average for period.	Number of barrels.	Average temperature.	Net weight of one barrel of water. Pounds.	Total weight collected in pounds.	Total.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.
1	March 8, 1897. 11 A. M. to 5 P. M.	6	156.340	22.334	2,059½	158.4	25.341	76°	439.33	11,133	1,855.6	83.08	11.71
2	5 P. M. to 10 P. M.	5	363.679	36.368	2,694½	269.5	26.208	79°	439.15	11,509	2,301.8	63.29	8.54
3	March 8 and 9. 10 P. M. to 5 A. M.	7	222.702	27.838	2,753	196.6	31.951	77°	439.28	14,035	2,005.0	72.02	10.20
4	March 9. 5 A. M. to 7'30 A. M.	2½	67.942	33.971	1,173	234.6	12.417	77°	439.28	5,455	2,181.8	64 23	9.30
5	7'30 A. M. to 11 A. M.	3½	94.050	23.512	1,077	153.9	14.624	75°	439.40	6,426	1,836.0	78.09	11.93
"	Total.	...	904.713	...	9,757	...	110.541	...	...	48,558	...	...	...
"	Divisor.	...	31	...	49	...	...	...	...	24	...	...	...
Average for 24 hours.....		...	29.184	...	199.1	...	...	...	...	2,023.3	...	69.33	10.16

Average steam per hour per I.H.P. for 24 hours $= \frac{2,023.3}{29.184} = 69.33$.

Average steam per hour per ampère for 24 hours $= \frac{2,023.3}{199.1} = 10.16$.

TEST No. 21, NOVEMBER 12, 1896.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 2 DYNAMO ENGINE AND STEAM CYLINDER OF STARBOARD AUXILIARY CONDENSER. DYNAMO ENGINE PISTONS GROOVED FOR WATER PACKING.

Test began at 1·12 P. M. Duration of test: First period, 2 h. 48 m. 00 s.; Second period, 1 h. 29 m. 06 s. Steam cylinder of auxiliary condenser not indicated.

	Time.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			Steam cyl. starboard aux cond.		No. 2 dynamo engine.							Condensed exhaust steam.									Temperature injection.
											Mean pressures.											Weight per hour, pounds.					
		Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Reading of counter.	Double strokes.	Revolutions.	For'd cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.*	Reading of voltmeter.	Number of barrels.	Total number of barrels for period.	Time full.	Time filling.	Temperature.	Total.	Used by steam cylinder of aux. condenser.	Used by dynamo engine.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.	
First Period.†	P. M.																		*h. m. s.*	*m. s.*							
	1·00	84	83	46	10	6¼	10	197,503	...	390	11.90	10.75	22.65	19.101	155	83	...	...	...	...	...						70
	1·30	91	91	46	10½	8½	10½	198,576	35·7	395	...	...	...	...	160	83	1	...	1·22·21	10·21	102						70
	2·00	94	94	47	10½	9¾	10½	199,582	33·5	390	12.30	9.65	21.95	18.510	160	81	2	...	1·31·50	9·29	102						70
																	3	...	40·51	9·01	102						
																	4	...	52·04	11·13	100						
	2·30	95	95	47	11	9½	10½	200,510	30.9	390	...	...	...	...	160	81	5	...	2·03·20	11·16	98						70
																	6	...	14·44	11·24	97						
																	7	...	25·52	11·08	97						
	3·00	94	94	47	11¼	10¼	11½	201,440	31 0	393	11.68	11.18	22.86	19 426	158	82	8	...	2·37·47	11·55	97						70
																	9	...	49·21	11·34	97						
																	10	...	3·00·34	11·13	97						
	3·30	98	97	47	11½	10¾	10	202,420	33.0	390	...	...	...	...	165	82	11	...	11·51	11·17	97						70
																	12	...	23·14	11·23	97						
																	13	...	3·34·36	11·22	97						
	4·00	110	109	49	13	12	13	203,414	33.1	390	...	...	...	...	165	82	14	...	45·59	11·23	97						70
																	15	15.2573	57·30	11·31	96						
	Average.....				...	...	...	...	32.9	...	...	...	...	19.012	160.4	..	...	...	...	...	98.2	2 385.3	318.49	2.066.8	108 71	12 88	...
Second Period.‡	4·30	115	115	46	13	13	13	204,370	31.9	390	16.37	17.30	33.67	28.394	335	83	16	...	4·07·13	9·43	98						70
																	17	...	17·04	9·51	101						
																	18	...	26·10	9·06	102						
	5·00	96	96	45	13	11½	13	205,330	32.0	390	19.02	18.12	37.14	31.320	340	81	19	...	4·35·11	9·01	103						70
																	20	...	44·20	9·09	104						
																	21	...	53·31	9·11	104						
																	22	...	5·02·47	9·16	104						
	5·30	106	106	45	13	12	13	206,360	34·3	386	18.81	18.75	37.56	31.349	345	80	23	...	11·50	9·03	104						70
																	24	...	20·11	8·21	104						
																	25	9.7427	29·06	8·55	104						
	Average.....				...	...	...	...	32 7	...	...	...	...	30 354	340	...	...	...	...	...	102·8	2 869 2	318 49	2,550.7	84.03	7.50	...

* Reading of ammeter unreliable.

† First period. . . Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in. . . Net weight of a barrel of water (temp. 98°) = 437 756 pounds.

Average.....	...	...	...	...	32 7	...	...	...	...	30 354	340	...	...	...	...	...	102'8	2 869 2	318 49	2,550.7	84.03	7.50	...

* Reading of ammeter unreliable.
† First period. Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in. . . Net weight of a barrel of water (temp. 98°) = 437.756 pounds.

*TEST No. 22, DECEMBER 1, 1896.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 2 DYNAMO ENGINE. PISTONS OF ENGINE GROOVED FOR WATER PACKING.

Test began: First period, 1'58 P. M.; duration of test, 2 hours 2 minutes 00 seconds. Second period, 4'00 P. M.; duration, 1 hour 33 minutes 25 seconds.

	Time.	Steam pressure. (Gauge.) Boiler.	Engine room.	Dynamo room.	Vacuum. (Inches.) Starboard engine room.	Center engine room.	Dynamo room.	No. 2 Dynamo engine. Revolutions.	Mean pressures. Forward cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.†	Reading of voltmeter.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Weight per hour, pounds. Total.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.	Temperature injection.
	P. M.															h. m. s.	m. s.					
First Period.‡	1'30	100	96	46	14	13½	11	393	11.12	9.62	20.74	17.617	145	83	...	...	...	...				69
	2'00	98	94	48	15	14	12	392	11.01	8.87	19.88	16.844	143	80	...	...	...	...				89
	2'30	92	88	48	14	13½	12	390	...	...	...	...	143	80	1	2'13'10	15'10	90	$\frac{438.46\times8\times60}{122}$ =	1,725.0 / 16.791 =	$\frac{1,725.0}{142\frac{2}{3}}$ =	69
															2	28'25	15'15	90				
	3'00	101	97	49	15	14½	12	392	10.95	8.78	19.73	16.716	142	80	3	2'43'30	15'05	90				69
															4	58'40	15'20	90				
	3'30	97	93	48	14	14	12	392	...	...	...	...	143	80	5	3'14'05	15'25	89				69
															6	29'30	15'25	89				
	4'00	99	95	48	14½	14	11	393	10.00	8.82	18.82	15.786	140	80	7	3'45'05	15'35	88				69
															8	4'00'00	14'55	88				
	Average.....	...	...	...	...	...	...	...	...	...	...	16.791	142⅔	...	...	...	...	89.2	1,725.0	102.73	12.09	...
Second Period.§	4'30	94	90	46	13	13	12	392	15.73	13.62	29.35	24 867	247	83	1	4'12'05	12'05	90	$\frac{437.9\times8\times60}{93.417}$ =	2,250.0 / 26.553 =	$\frac{2,250.0}{269}$ =	69
															2	24'05	12.00	93				
	5'00	89	85	44	12	11½	10	390	16.63	15.05	31.68	26.705	260	82	3	4'36'20	12'15	96				69
															4	48 55	12'35	96				
	5'30	95	91	45	14	12½	11	390	17.87	15.45	33.32	28.086	300	82	5	5'00'35	11'40	98				69
															6	11'35	11'00	99				
															7	22'30	10 55	100				
															8	33 25	10 55	99				
	Average.....	...	...	...	...	...	...	...	...	...	...	26.553	269	...	...	...	...	96.4	2,250.0	84.74	8.36	...

* Made for comparison with Test No. 21 of November 12.
† Reading of ammeter unreliable.
‡ First period. Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in. . . Net weight of a barrel of water (temp. 89°) = 438.46 pounds.
§ Second period. Added circuits 8, 9, 10 and 11. . . . . Net weight of a barrel of water (temp. 96°) = 437.9 pounds.

TEST No. 23, JANUARY 1, 1897.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 2 DYNAMO ENGINE. NEW PISTONS WITH RINGS IN PLACE, HAVING BEEN IN USE ABOUT NINE DAYS.

Test began: First period, 3'25 P. M.; duration of test, 1 hour 10 minutes 25 seconds. Second period, 4'44 P. M.; duration, 26 minutes 25 seconds.

	Time.	Steam pressure. (Gauge.) Boiler.	Engine room.	Dynamo room.	Vacuum. (Inches.) Starboard engine room.	Center engine room.	Dynamo room.	No. 2 Dynamo engine. Revolutions.	Mean pressures. Forward cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.*	Reading of voltmeter.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Weight per hour, pounds. Total.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.	Temperature injection.
First Period.†	P. M.															*h. m. s.*	*m. s.*					
	3'30	110	101	67	15	14½	14	425	12.87	11.62	24.49	22.496	152	82	...	...	...	...				68
	4'00	103	96	65	15	12½	14	425	...	...	...	...	159	82	1	3'42'25	17'25	98	$\frac{437.98\times4\times3,600}{4,235}=$	$\frac{1,492.7}{22.923}=$	$\frac{1492.7}{160.3}=$	68
	4'30	103	97	67	17	14	15	425	13.75	11.67	25.42	23.350	170	82	2 3 4	4'00'15 17'35 35'25	17'50 17.20 17'50	92 94 98				68
	Average.....				...	...	...	...	...	...	...	22.923	160.3	...	...	...	...	94.5	1,492.7	65.12	9.31	...
Second Period.‡	5'00	100	94	63	17	13	15	425	...	...	...	...	232	81	1	4'59'50	15'50	92	$\frac{437.9\times2\times3,600}{1,583}=$	$\frac{1,989.2}{35.237}=$	$\frac{1,989.2}{273}=$	68
	5'15	...	...	...	...	...	...	...	19.93	18.67	38.60	35.457	...	...	2	5'15'45	15'55	92				...
	5'30	94	87	60	16	12	14½	425	19.67	18.45	38.12	35.016	273	82	3 4	29'00 42'10	13'15 13'10	94 98				68
	Average				...	...	...	...	...	...	...	35.237	273	...	...	...	...	96	1,989.2	56.45	7.29	

On account of indicator string breaking during the second period, cards were not taken during time the first two barrels were filling. Calculations for this period are based on time of collecting last two barrels.

* Ammeter out of order; reading given is calculated from number of lights burning.

† First period. Circuits 1, 2, 3, 4, 5, 6, 7, 8 and 11 and two motors cut in. . . Net weight of a barrel of water (temp. 95°) = 437.98 pounds.

‡ Second period. Added circuits 9 and 10. . . . . Net weight of a barrel of water (temp. 96°) = 437.9 pounds.

TEST No. 24, NOVEMBER 13, 1896.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 3 DYNAMO ENGINE AND STEAM CYLINDER OF STARBOARD AUXILIARY CONDENSER. DYNAMO ENGINE PISTONS GROOVED FOR WATER PACKING.

Test began at 2·00 P. M. Duration of test: First period, 2 h. 00 m. 00 s.; Second period, 1 h. 35 m. 26 s. Steam cylinder of auxiliary condenser not indicated.

	Time.	Steam pressure. (Gauge.)			Vacuum. (Inches.)			Steam cyl. starboard aux. cond.		No. 3 dynamo engine.					Reading of ammeter.	Reading of voltmeter.	Condensed exhaust steam.								Temperature injection.
											Mean pressures.						Number of barrels.	Total number of barrels for period.	Time full.	Time filling.	Temperature.	Weight per hour, pounds.					
		Boiler.	Engine room.	Dynamo room.	Starboard engine room.	Center engine room.	Dynamo room.	Reading of counter.	Double strokes.	Revolutions.	For'd cylinder.	After cylinder.	Total.	I H.P.							Total.	Used by steam cylinder of aux. condenser.	Used by dynamo engine.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.	
	P. M.																		*h. m. s.*	*m. s.*							
First Period.*	1·30	97	97	48	13½	11	12	208,132	32.5	398	...	...	...	...	155	80	...	...	...	...	...						70
	2·00	104	104	48	14½	10	12	209,108	34.5	408	9.87	11.00	20.87	18.411	160	82	...	...	...	...	...						70
	2·30	103	103	50	15	11	13	210,142	32.5	410	...	...	...	...	162	82	1	...	2·12·47	12·47	96						70
																	2	...	25·18	12·31	96						70
	3·00	108	108	50	15	11	13	211,171	34.3	410	9.43	10.81	20.24	17.943	162	82	3	...	2·37·48	12·30	96						70
																	4	...	50·17	12·19	96						70
	3·30	111	111	51	15	12	13½	212,160	33.0	410	...	...	...	...	155	81	5	...	3·02·55	12·38	95						70
																	6	...	16·00	13·05	96						70
																	7	...	29·09	13·09	96						70
	4·00	109	109	51	15	12	13½	213,127	32.2	590	8.77	9.75	18.52	15.618	165	77	8	...	3·42·25	13·16	95						70
																	9	9.2318	57·14	14·49	94						70
	Average.....	...	...	...	...	...	...	...	33.2	...	...	...	...	...	159.8	...	...	...	...	...	95.5	2,021.48	328.07	1,693.4	97.75	10.60	70
Second Period.†	4·30	110	110	48	15	12	13½	214,113	32.9	402	13.30	15.67	28.97	25.182	245	84	10	...	4·09·10	11·56	97						70
																	11	...	20·41	11·31	97						70
	5·00	108	108	48	15	15	13½	215,152	34.6	383	15.22	16.05	31.27	25.896	265	82	12	...	4·31·21	10.40	97						70
																	13	...	41·58	10·37	98						70
																	14	...	52·52	10·56	98						70
																	15	...	5·03·40	10·48	98						70
																	16	...	14·20	10·40	98						70
																	17	...	24·57	10·37	99						70
	5·30	109	109	48	15	12	13½	216,116	32.1	380	16.12	17.50	33.62	27.624	270	80	18	8.7682	35·26	10·29	100						70
	Average.....	...	...	...	...	...	...	...	33.2	...	...	...	...	...	2,6 234	260	...	...	...	...	98.0	2,413.2	328.07	2,085.1	79.48	8.02	70

* First period. Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in. . . Net weight of a barrel of water (temp. 95.5°) = 437.94 pounds.
† Second period. Added circuits 8, 9, 10 and 11. . . . . Net weight of a barrel of water (temp. 98°) = 437.756 pounds.

TEST No. 25, NOVEMBER 30, 1896.—COLLECTING CONDENSED EXHAUST STEAM FROM No. 3 DYNAMO ENGINE. NEW PISTONS WITH RINGS IN PLACE, HAVING BEEN IN USE ABOUT FOUR DAYS.

Test began: First period, 1'33 P. M.; duration of test, 2 hours 03 minutes 45 seconds. Second period, 3'50'45 P. M.; duration, 1 hour 44 minutes 50 seconds.

	Time.	Steam pressure. (Gauge.) Boiler.	Engine room.	Dynamo room.	Vacuum. (Inches.) Starboard engine room.	Center engine room.	Dynamo room.	No. 3 Dynamo engine. Revolutions.	Mean pressures. Forward cylinder.	After cylinder.	Total.	I.H.P.	Reading of ammeter.	Reading of voltmeter.	Condensed exhaust steam. Number of barrels.	Time full.	Time filling.	Temperature.	Weight per hour, pounds. Total.	Used by dynamo engine per I.H.P.	Used by dynamo engine per ampère.	Temperature injection.
First Period.*	P. M.															h. m. s.	m. s.					
	1'30	98	94	50	14	11	12½	400	...	...	...	...	155	82	...	...	...	...				69
	2'00	102	98	50	15	14	13	400	11.75	10.46	22.21	19.202	152½	80	1	1'50'30	17'30	88				69
	2'30	106	102	50	15	15	13	400	...	...	...	...	152½	80	2	2'08'15	17'45	86				69
															3	25'50	17'35	85				
	3'00	99	95	50	14½	14	13	400	10.08	10.52	20.60	17.810	152½	80	4	2'43'40	17'50	85				69
	3'30	100	96	50	14½	14½	13	390	9.81	11.20	21.01	17.710	150	81	5	3'01'30	17'50	85	$\frac{438.672 \times 7 \times 60}{123.75} =$	$\frac{1,488.8}{18.241} =$	$\frac{1,488.8}{152.5} =$	69
															6	19'20	17'50	85				
															7	36'45	17'25	85				
	Average.....	...	...	...	...	...	...	...	...	...	...	18.241	152½	...	...	...	...	85.6	1,488.8	81.62	9.76	...
Second Period.†	4'00	97	93	47½	14	13	12	380	15.12	16.35	31.47	25.847	235	80	...	...	...	...				69
	4'30	98	94	47½	14	13½	12	380	...	...	...	...	250	81	1	4'04'25	13'40	90				70
															2	18'10	13'45	91				
															3	4'31'30	13'20	90				
	5'00	98	94	47½	13	13½	11	380	15.37	17.37	32.74	26.890	255	80	4	44'40	13'10	92	$\frac{438.227 \times 8 \times 60}{104.833} =$	$\frac{2,006.5}{27.815} =$	$\frac{2,006.5}{255.25} =$	70
															5	58'15	13'35	92				
															6	5'10'55	12'40	92				
	5 30	100	96	47	14	13	10½	390	17.43	19.00	36.43	30.708	281	83	7	23'10	12'15	94				70
															8	35'35	12'25	94				
	Average.....	...	...	...	...	...	...	...	...	...	...	27.815	255¼	...	...	...	...	91.9	2,006.5	72.14	7.86	...

* First period. Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in. . . Net weight of a barrel of water (temp. 86°) = 438.672 pounds.

† Second period. Added circuits 8, 9, 10 and 11. . . . . Net weight of a barrel of water (temp. 92°) = 438.227 pounds.

In July, 1895, while the *Minneapolis* was at the Norfolk navy yard, the steam consumption of No. 3 dynamo engine was determined in a different way from the preceding tests. For comparison, the results are given in test No. 26.

The method employed was to weigh the feed water pumped into the forward auxiliary boiler which only provided steam for the engine under test, the after auxiliary boiler being also in use to furnish steam for all other machinery in operation. A small tank, so placed as to be readily filled from the dock hydrant, was used to weigh the feed water, and this emptied by gravity into the starboard main feed tank. The latter served as a reservoir from which the feed pump supplied the forward auxiliary boiler, and was disconnected from the port tank into which the port auxiliary air pump delivered the condensed exhaust steam from all machinery running.

Steam was supplied to the dynamo engine through a special direct line of piping to which there were no other auxiliary connections; all water collecting in the dynamo separator, due to radiation of piping and other causes, was drained off and weighed.

Several hours before starting the test, the tubes and fires were cleaned; at the beginning, the appearance of the fires was noted and the water level marked on the gauge glass; these were left in the same condition at the end.

Eureka bituminous coal of indifferent quality was used.

Following are the principal dimensions of the boiler, and a summary of the test.

BOILER.

Diameter, feet and inches	10– 1¾
Length, feet and inches	8– 6
Number of furnaces, corrugated	2
Diameter of furnaces, outside, inches	37
Diameter of furnaces, inside, inches	33
Length of grate, inches	70
Grate surface, square feet	32
Number of tubes	216
Outside diameter of tubes, inches	2½
Heating surface, square feet	976
Ratio G.S. to H.S.	1 to 30.5

* First period. Circuits 1, 2, 3, 4, 5, 6 and 7 and one motor cut in. . . . Net weight of a barrel of water (temp. 60°) = 430.277 pounds.
† Second period. Added circuits 8, 9, 10 and 11. . . . . Net weight of a barrel of water (temp. 92°) = 430.277 pounds.

SUMMARY OF TEST No. 26.

Duration of test, hours	12
Average steam pressure at boiler, pounds	83
Coal consumed, pounds	3,112
Refuse, pounds	352.5
Combustible, pounds	2,759.5
Coal per hour, pounds	259.33
Coal per hour per square foot of grate, pounds	8.10
Per cent. of refuse in coal	11.32
Total feed water vaporized, pounds	23,936
Water drained from separator, pounds	386
Steam used by dynamo engine, pounds	23,550
Average water used by dynamo engine per hour, pounds	1,962.5
Mean temperature of feed water, degrees	77 5
Pounds of water vaporized per pound of coal	7.69
Pounds of water vaporized per pound of combustible	8.67
Equivalent evaporation per pound of coal from and at 212°	9.04
Equivalent evaporation per pound of combustible from and at 212°	10.19
Mean I.H.P. for test	20.04
Coal per I.H.P. per hour, pounds	12.73
Water per I.H.P. per hour, pounds	97.92

TEST No. 26, JULY 13, 1895. No. 3 DYNAMO ENGINE.

Date and hour.	Steam pressure. (Gauge.)		Vacuum (inches), dynamo room.	No. 3 dynamo engine.					Reading of ammeter.	Reading of voltmeter.	Feed water.		Coal consumed, in pounds.	Refuse, pounds.
					Mean pressures.									
	Auxiliary boiler.	Dynamo room.		Revolutions.	For'd cylinder.	After cylinder.	Total.	I.H.P.			Temperature.	Amount evaporated, in pounds.		
July 13, '95. P. M.														
8·00	81	60	10	390	14.25	14.00	28.25	23.80	220	82.5	78	...	...	...
9·00	57	37	11	390	14.25	12.50	26.75	22.54	195	80.5	78	...	400	...
10.00	87	61	11	390	12.75	10.50	23.25	19.59	165	82 5	78	...	296½	...
11·00	94	63	11	390	12.50	10.00	22.50	18.96	172	80	77	...	304½	...
12.00	93	63	13	390	12.50	11.00	23.50	19.80	167	80	78	...	302	...
July 14. A. M.														
1·00	83	55	12	390	12.25	10.50	22.75	19.16	168	8.05	77½	...	303½	...
2·00	76	53	12	390	13.00	11.00	24.00	20 22	167	80 5	78	...	300½	...
3·00	88	56	12	390	12.25	10.75	23.00	19.38	165	80	77½	...	303	...
4·00	73	55	12	390	13.50	10.75	24.25	20.43	171	80	76½	...	100	...
5·00	72	53	11½	390	12 00	11.00	23 00	19.38	164	80	78	...	97½	...
6·00	97	65	11½	390	12.00	10.25	22.25	18.74	154	80	77	...	295½	...
7·00	90	61	10	390	12.50	10.50	23.00	19.38	156	80	77	...	205	...
8·00	89	62	12	390	11.75	11.00	22.75	19.17	154	80	77	23.936	204	352½
Average...	83	57.2	11¼	390	12.73	11.06	23.79	20.04	170.6	80.5	77½	1,994⅔	259⅓	...

Flushing pump in evaporator room on flushing main; Davidson, horizontal, single-cylinder.—Test No. 27, February 25, 1897.

Speed of pump regulated to keep the "head" well flushed.

Diameter of steam cylinder, inches..... 8
Diameter of water cylinder, inches..... 9
Diameter of piston rod, inches..... $1\frac{7}{16}$
Stroke, full, inches..... 12
Average stroke during test, inches..... $10\frac{1}{2}$

Test began at 4·02 P. M.

Time.	Steam pressure. Boiler.	Steam pressure. Engine room.	Steam pressure. Evaporator room.	Vacuum. Starboard engine room.	Vacuum. Port engine room.	Flushing pump. Counter.	Flushing pump. Double strokes.	Flushing pump. Mean pressure.	Flushing pump. I.H.P.	Condensed exhaust steam. Number of barrels.	Condensed exhaust steam. Time full.	Condensed exhaust steam. Time filling.	Condensed exhaust steam. Temperature.	Injection.
P. M.											*h. m. s.*	*h. m. s.*		
4·00	110	108	100	20	20½	990	...	...	...	...	.....	.....	...	62
4·30	118	116	105	20	19	2,043	35.1	16.43	1.390	...	.....	.....	...	62
5·00	117	114	102	19½	18	2,923	29.4	...	...	...	.....	.....	...	62
5·30	110	108	98	18½	18	3,770	28.2	19.10	1.561	...	.....	.....	...	62
6·00	110	108	98	19½	19½	4,793	34.1	...	...	1	5'41"10	1'39"10	75	62
6·30	117	115	103	19	19½	5,823	34.3	15.50	1.362	...	.....	.....	...	62
7·00	120	118	107	19½	19	6,804	32.7	...	...	...	.....	.....	...	62
7·30	123	120	110	19½	19½	7,639	27.8	18.81	1.372	2	7'13"15	1'32"05	75	62
Average.....	...	...	...	.....	31.7	.....	1.421	...	.....	.....	75	...		

Net weight of a barrel of water (temp. 75°) = 439.4 pounds.

Duration of test..... 3 h. 11 m. 15 s.
Total weight of water collected, pounds..... 878.8
Total weight of water collected per hour, pounds..... 275.7
Total weight of water collected per hour, per I.H.P., pounds..... 194.02

Ship's ventilating blowers; Sturtevant, two-cylinder, simple, double-acting engine, with cranks at 180°. One piston valve, without packing rings, controls the admission and emission of steam to both cylinders.—Test No. 28, December 27, 1896.

Diameter of cylinders, inches..... 4
Stroke, inches..... 3
Diameter of fan, inches..... 48
Diameter of piston valve, inches..... $2\frac{1}{4}$
Travel of piston valve, inches..... 2

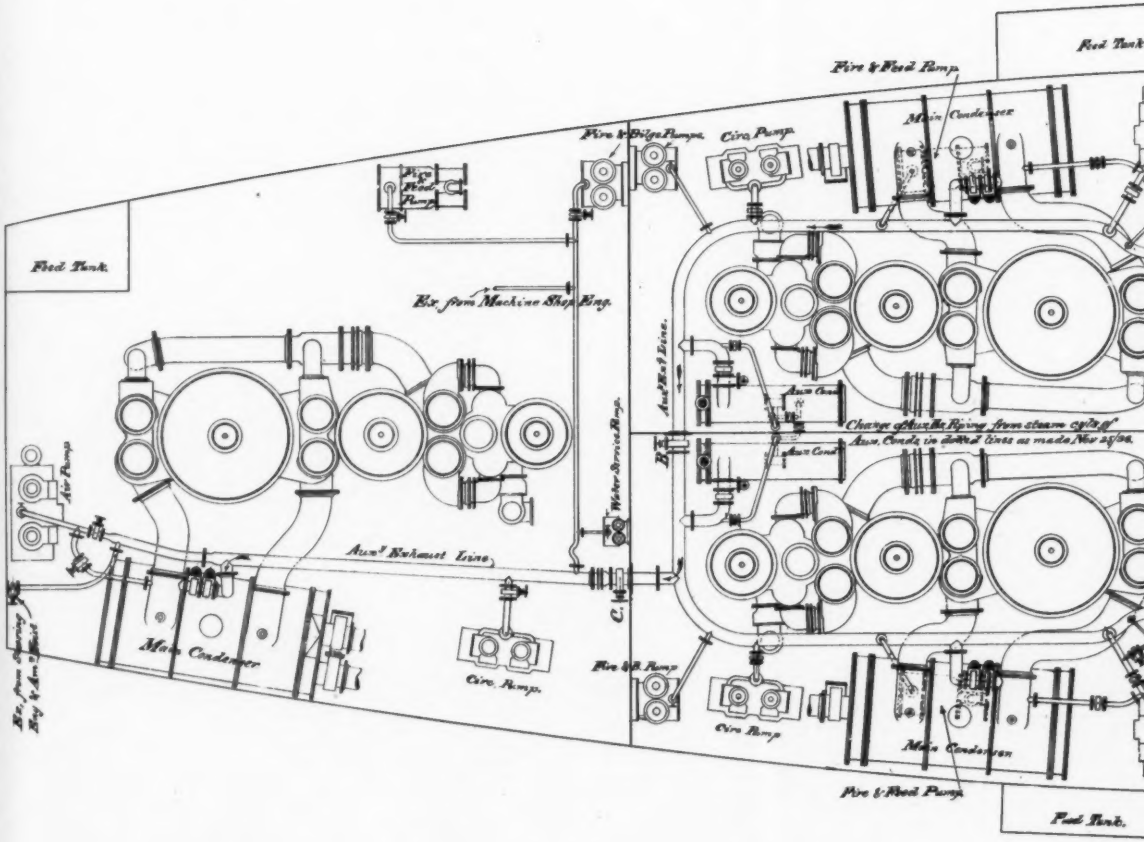
Four blowers of the above type are used for the ship's artificial ventilation below decks. These are arranged to exhaust from or force air to the several parts of the vessel through ducts, the change from one system to the other being readily made by means of a reversible valve. In the following test, the blowers ran on the exhaust system. No indicator cards were taken.

Test began: First period, 1.29 P. M. Second period, 3.44 P. M.

	Time.	Steam pressure.		Vacuum.			Revolutions of blowers.					Condensed exhaust steam.				
							Starboard.		Port.							
		Boiler.	Engine room.	Starboard engine room.	Port engine room.	Center engine room.	Forward.	Aft.	Forward.	Aft.	Average of blowers for period.	Number of barrels.	Time full.	Time filling.	Temperature.	Injection.
First Period.	P. M.												*h. m. s.*	*m. s.*		
	1·30	91	87	15	14	12	247	247	262	276	...	...	.....	.....	...	68
	2·00	90	86	17	15	12	259	271	293	301	...	1	1·52 35	23·35	84	68
	2·30	94	90	16	15	13	266	265	297	312	...	2	2·16·15	23·40	84	68
	3·00	93	89	16	15	13	275	272	294	290	...	3	2·40·30	24·15	84	68
	3·30	92	88	16½	15	13	266	276	284	297	...	4	3·05·00	24·30	84	68
												5	3·28·50	23·50	84	68
	Average			...	...	...	262.6	266.2	286	295.2	277.5	...	.....	.....	84	...
Second Period.	4·00	91	87	15½	14	13	400	415	426	400	...	1	3·56·10	12·10	87	68
	4·15	83	79	13½	12	12	388	404	423	399	...	2	4·08·45	12·35	88	68
	4·30	84	80	13	12	12	388	405	411	392	...	3	4·22·20	13·35	88	68
												4	4·36·30	14·10	88	
	Average			...	...	...	392	408	420	397	404.3	...	.....	.....	87.8	...

First Period. Net weight of a barrel of water (temp. 84°) = 438.81 pounds.
Second Period. Net weight of a barrel of water (temp. 88°) = 438.53 pounds.

Duration of test, first period..... 1 h. 59 m. 50 s.
Duration of test, second period..... 52 m. 30 s.
Total weight of water collected, first period, pounds..... 2,194.05
Total weight of water collected, first period, per hour, pounds..... 1,098.60
Total weight of water collected, first period, per hour, per blower, pounds... 274.65
Total weight of water collected, second period, pounds..... 1,754.12
Total weight of water collected, second period, per hour, pounds..... 2,004 90
Total weight of water collected, second period, per hour, per blower, pounds, 501.23


Fire & Feed Pump.
Main Condenser
Fire & Bilge Pumps.
Circ. Pump.
Feed Tank.
Bilge Feed Pump
Exr. from Machine Shop Eng.
Aux. Feed Line.
Aux. Cond.
Change of Aux. Ex. Piping from steam cyls. to Aux. Condrs. in dotted lines as made Nov 25/98.
Air Pump
Water Service Pump.
Aux. Exhaust Line.
C. W.
Main Condenser
Circ. Pump.
Fire & B. Pump
Exr. from Steering Eng. & Aux. Boiler
Circ. Pump
Main Condenser
Fire & Feed Pump.
Feed Tank.

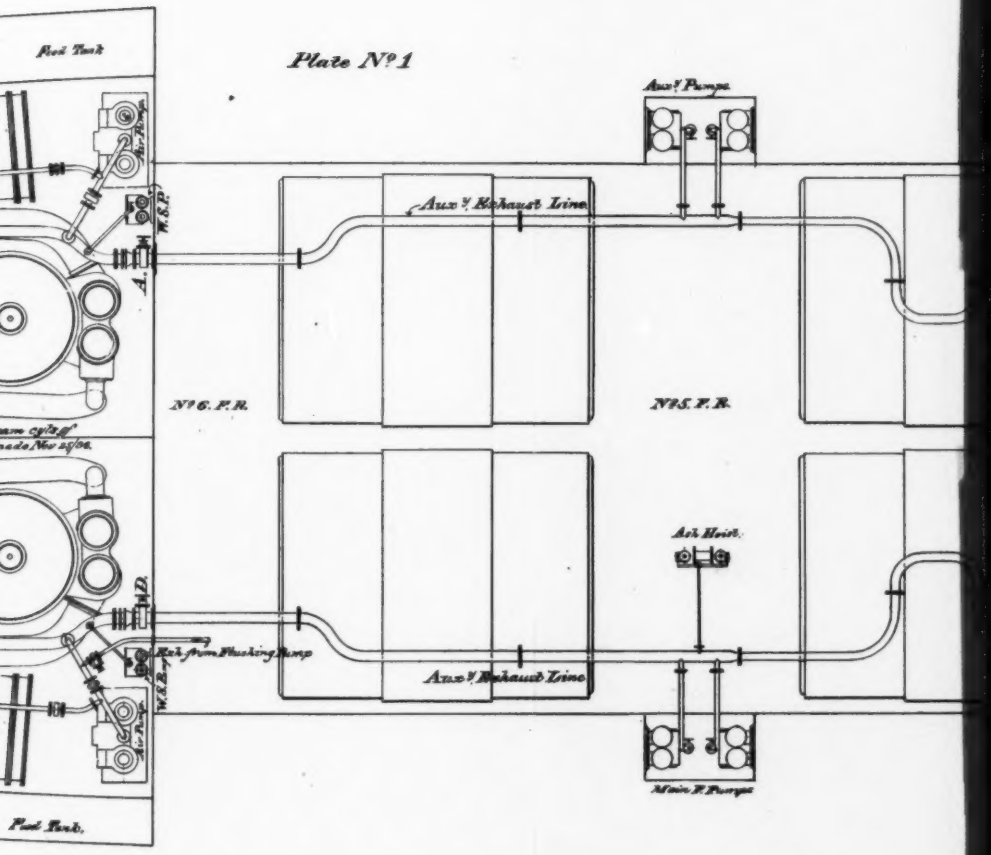
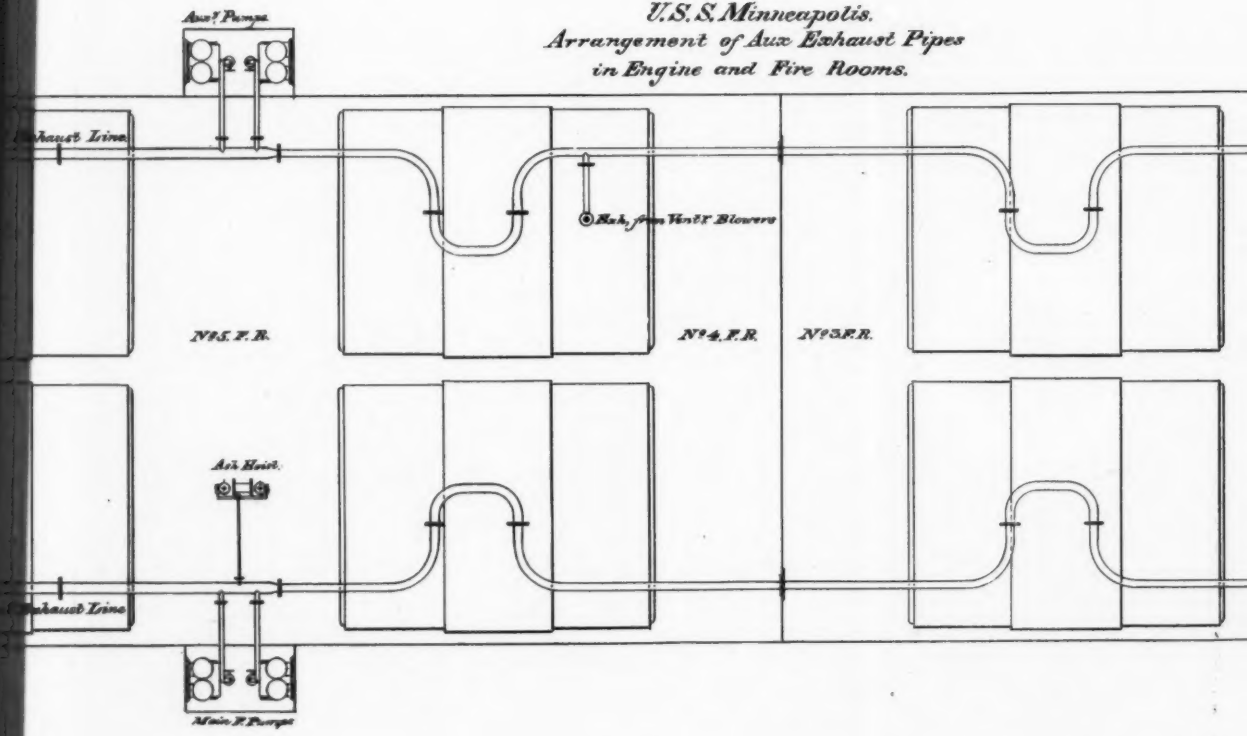
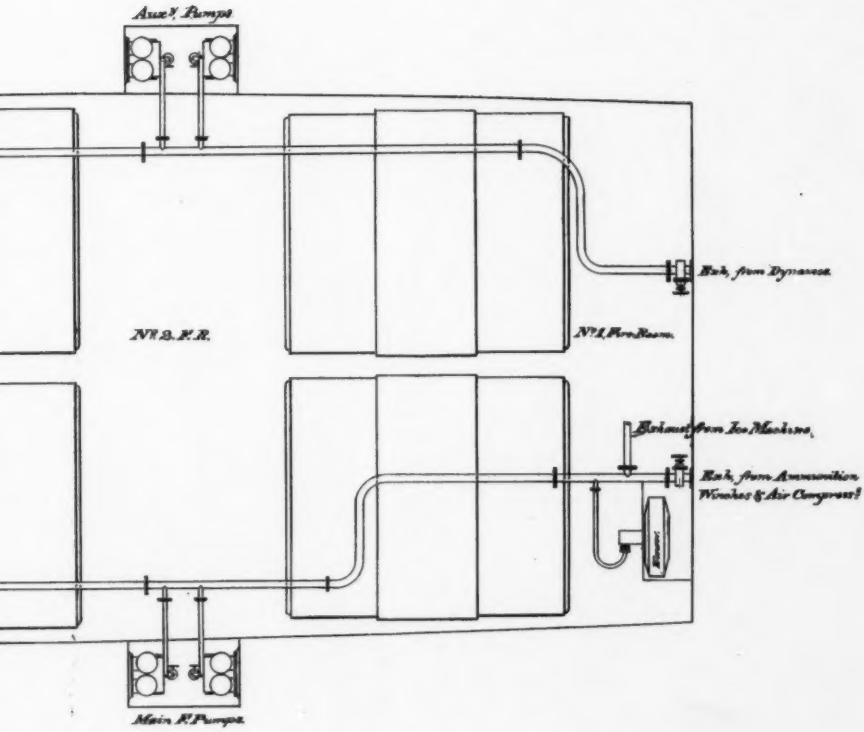


Plate Nº 1
Aux.y Pumps
Aux.y Exhaust Line
Nº 6. F. R.
Nº 5. F. R.
Ash Hoist.
Aux.y Exhaust Line
Main F. Pumps
Fuel Tank.

U.S.S. Minneapolis.
Arrangement of Aux Exhaust Pipes
in Engine and Fire Rooms.




Aux.y Pumps
Exh. from Dynamos
No 2. E.R.
No 1. Fire Room.
Exhaust from Ice Machine.
Exh. from Ammonia Ice Machine Winches & Air Compressor
Boiler
Main F. Pumps

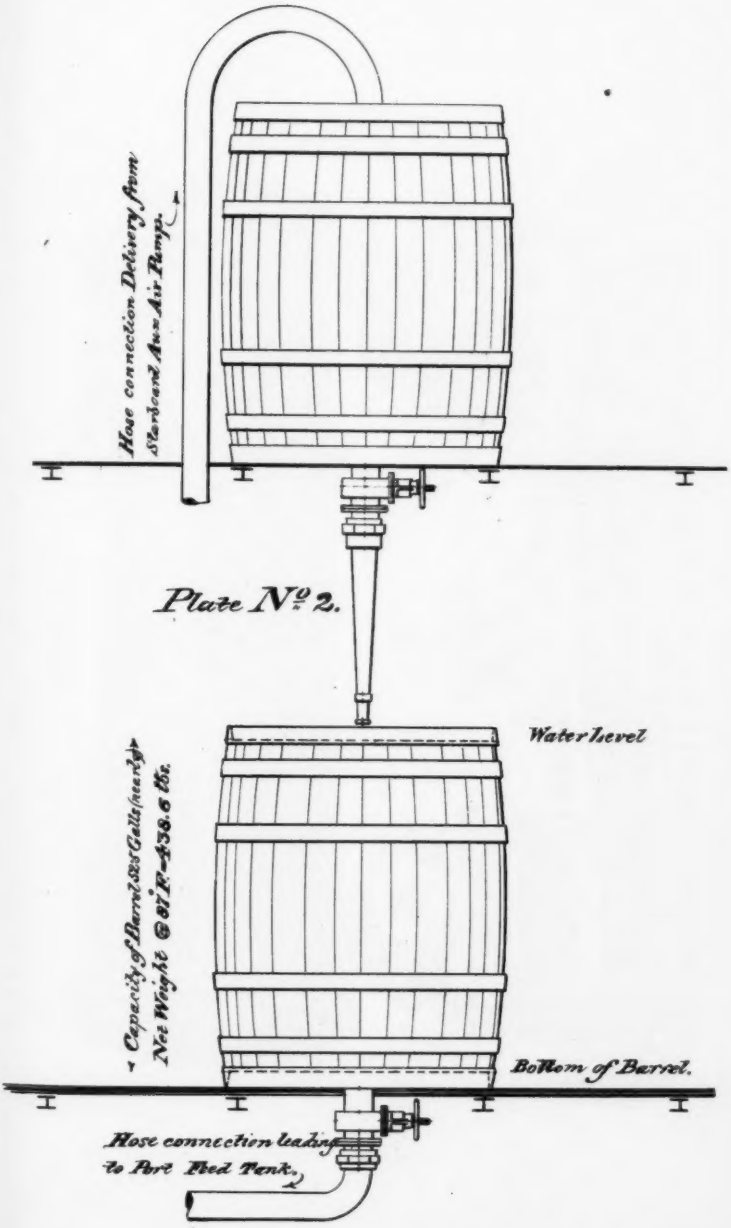
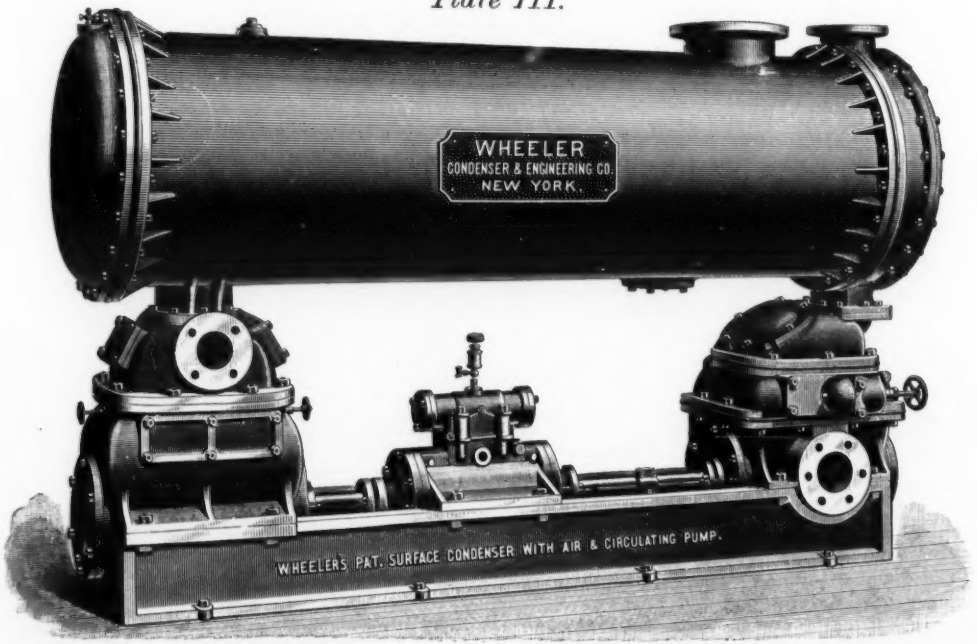

Hose connection Delivery from Starboard Aux. Air Pump.
Water Level
Capacity of Barrel 32 Gallons (heavy)
Net Weight @ 81° F. = 438.6 lbs.
Bottom of Barrel.
Hose connection leading to Port Feed Tank.

Plate No. 2.

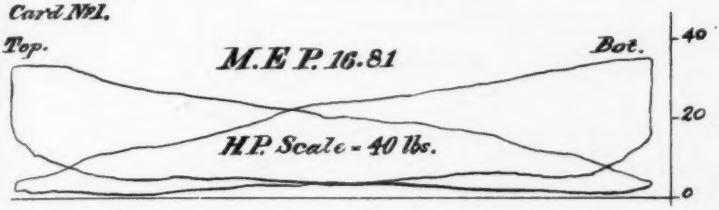
Plate III.


WHEELER
CONDENSER & ENGINEERING CO.
NEW YORK.
WHEELERS PAT. SURFACE CONDENSER WITH AIR & CIRCULATING PUMP.

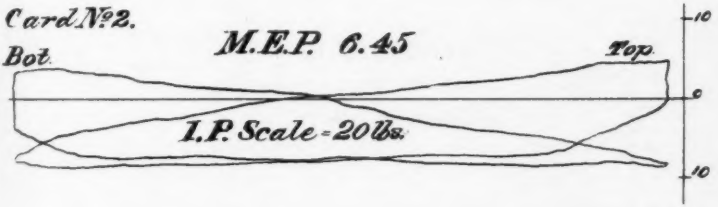
Test No. 1 (F.) Jany 1st 1897.

Starboard Main Engine.

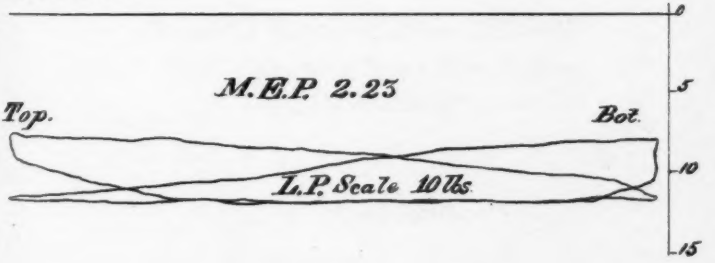
Card No. 1.



Card No. 2.



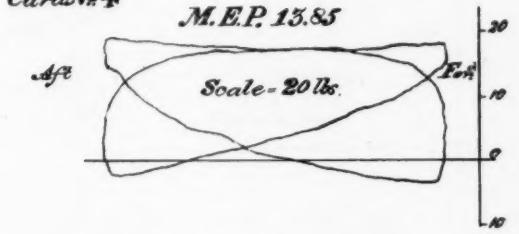
Card No. 3.



Test No 3 (2.30 P.M.) Nov 9th 1897.

Steam Cyl of Sturboard Aux Condenser.

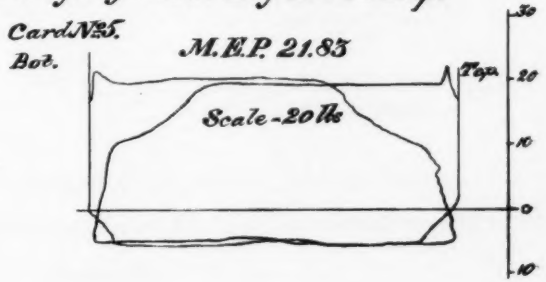
Card No 4



Test No 4 (5.30 PM) Nov 10th 1896.

For'd Cyl'r of Centre Eng Circ'g Pump.

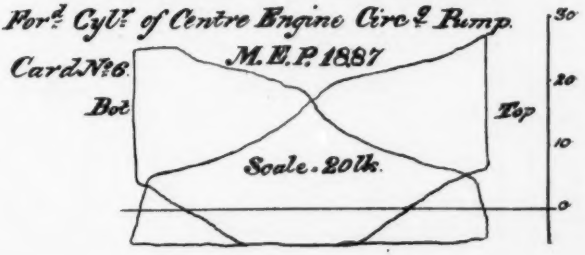
Card No 5.



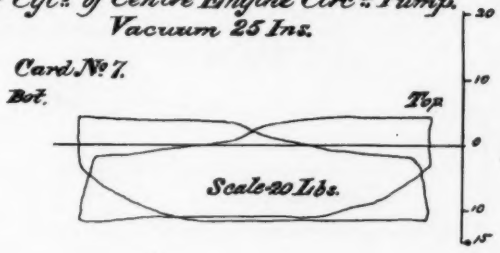
Test No 5 (4.00 P.M) Mar 3rd 1897.

For'd Cyl'r of Centre Engine Circ'g Pump.

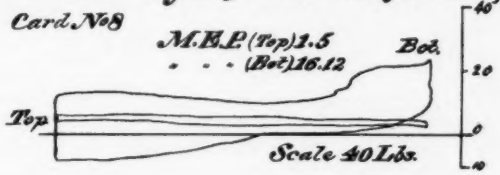
Card No 6.



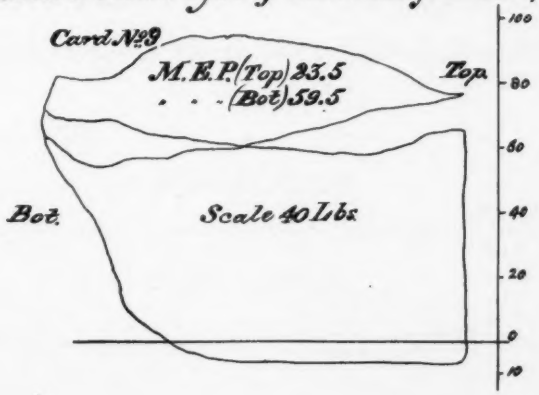
For.d Cyl.r of Centre Engine Circ.g Pump.
Vacuum 25 Ins.



Test No. 8 (6.00 P.M) Dec.r 4th 1896.
Outboard steam Cyl.r of Starb.d Eng. Air Pump



Test No. 9 (3.30 P.M) Nov 11th 1896.
Outboard steam Cyl.r of Centre Eng. Air Pump

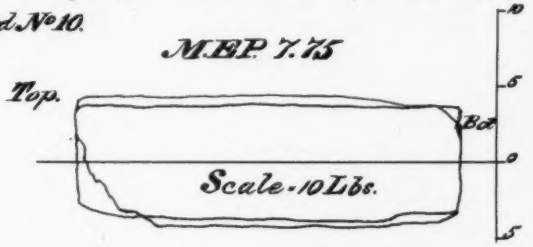


Test No 10 (7.30 P.M) Feby 4th 1897.

Outboard steam Cyl of Starbd Water Service Pump

Card No 10.

M.E.P. 7.75

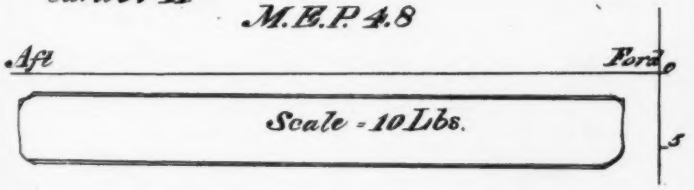


Test No 11 (6.00 P.M) Decr 2nd 1896.

Outboard steam Cyl of Centre Eng R. Fire & Feed Pump

Card No 11

M.E.P. 4.8

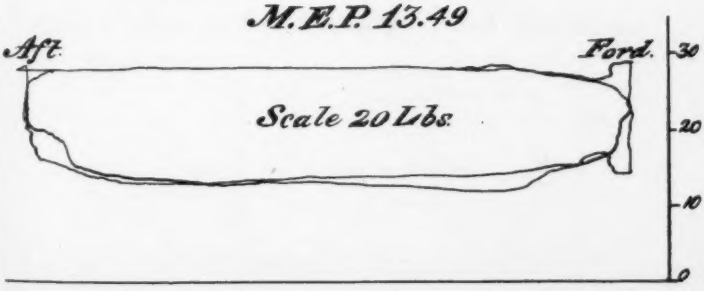


Test No 12 (6.15 P.M) Decr 3rd 1896.

Outboard steam Cyl of Centre Eng R. Fire & Feed Pump

Card No 12.

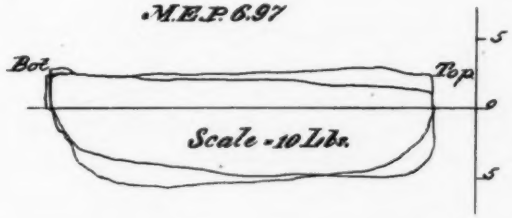
M.E.P. 13.49



Test No 13 (7.00 P.M) Feby 1st 1897.

Outboard steam Cyl of Centre Eng R. Fire & Bilge Pump.

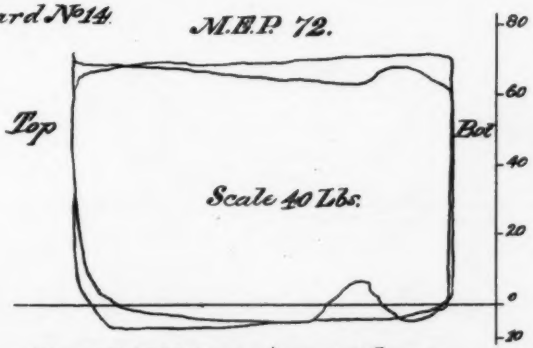
Card No 13.



Test No 14 (2.30 P.M) Decr 24th 1896

Inboard steam Cyl of Main (No 2) Fire R. Feed Pump.

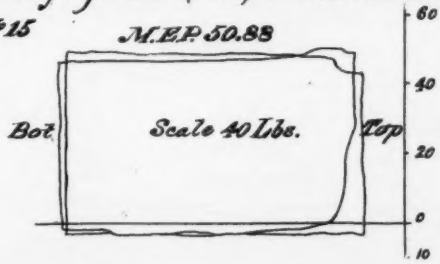
Card No 14



Test No 15 (5.30 P.M) Feby 18th 1897.

Inboard steam Cyl of Main (No 5) Fire R. Feed Pump.

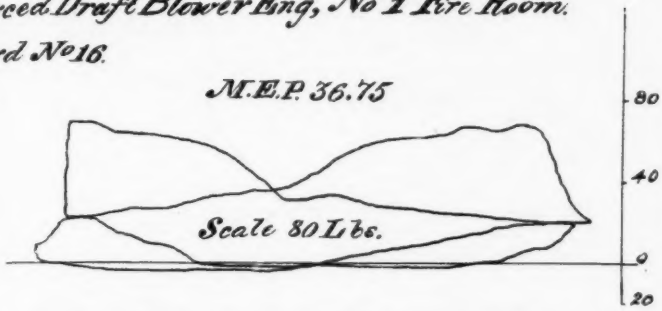
Card No 15



Test No 16. (6.00 P.M.) March 5th 1897.

Forced Draft Blower Eng, No 1 Fire Room.

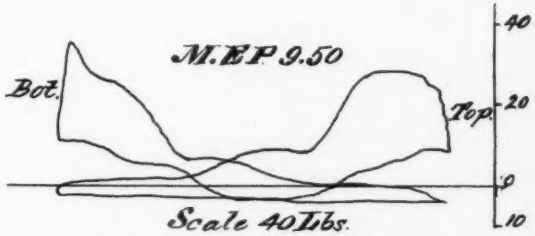
Card No 16.



Test No 18 (11.00 AM) Nov 7th 1896.

For^{d} Cyl^{r} of No 1 Dynamo Engine.

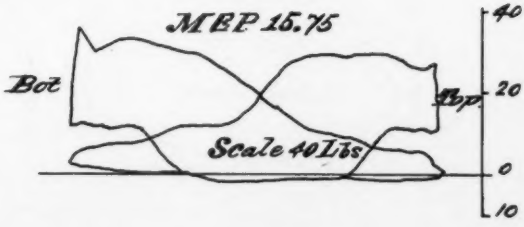
Card No 17



Test No 18 (7.30 PM) Nov 7th 1896.

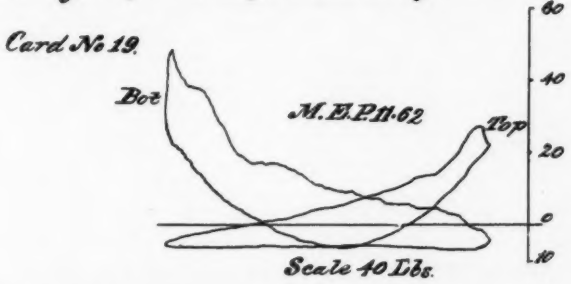
For^{d} Cyl^{r} of No 1 Dynamo Engine.

Card No 18.



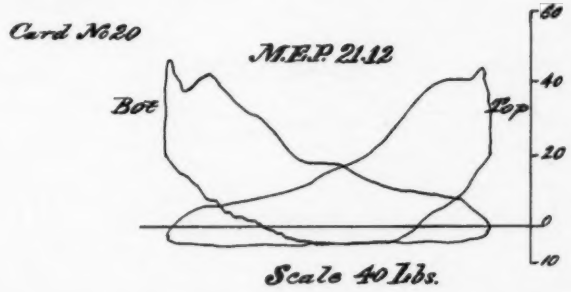
Test № 20 (11.00 A.M.) March 8th 1897.

Ford Cylr of № 1 Dynamo Engine.



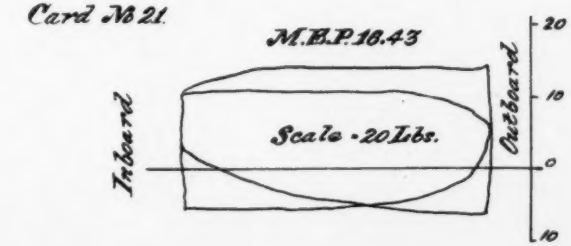
Test № 20 (7.30 P.M.) March 8th 1897.

Ford Cylr of № 1 Dynamo Eng.



Test № 27 (February 25th 1897.

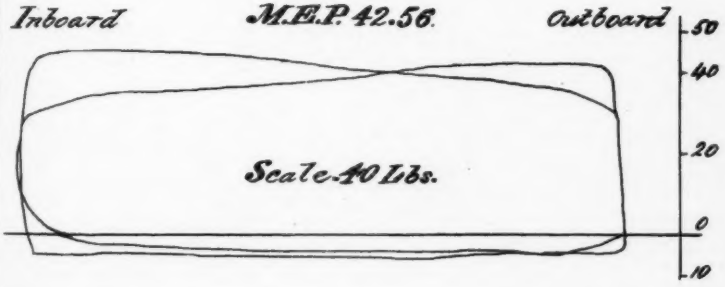
Steam Cylinder of Flushing Pump.



Test No 29 (10.45 P.M) Dec^{r}. 2nd. 1896.

Steam Cyl^{r}. of Ice Machine.

Card No 22.



One-ton Allen dense air ice machine; Single-cylinder, double-acting, horizontal engine.—Test No. 29, December 2, 1896.

Diameter of steam cylinder, inches..... 7
Diameter of piston rod, inches..... 1¼
Stroke, inches..... 10

Test began at 9 15 A. M.

Time.	Steam pressure. Boiler.	Steam pressure. Engine room.	Steam pressure. At ice machine.	Vacuum Starboard engine room.	Vacuum Port engine room.	Ice machine. Revolutions.	Ice machine. Mean pressure, steam cylinder.	Ice machine. I.H.P.	Ice machine. Air pressure. (Gauge.) Compression cylinder.	Ice machine. Air pressure. (Gauge.) Expander cylinder.	Condensed exhaust steam. Number of barrels.	Condensed exhaust steam. Time full.	Condensed exhaust steam. Time filling.	Condensed exhaust steam. Temperature.	Injection.
A. M.												*h. m. s.*	*h. m. s.*		
9'15	99	98	54	15½	16½	77	...	...	282	89	...	.....	.....	...	67
9'45	103	101	52	17	16	72	...	...	277	89	...	.....	.....	...	67
10'15	105	103	50	17	17½	75	...	...	277	88	1	10'11'20	56'20	75	67
10'45	103	102	49	15¾	17	74	42.56	6.024	280	88	...	.....	.....	...	67
11'15	98	96	46	17	16¾	72½	...	...	270	86	2	11'11'50	1'00'30	75	67
11'45	95	93	51	17	16½	75½	...	...	281	88	...	.....	.....	...	67
P. M.															
12'15	87	86	50	16½	18	71	...	...	273	86	...	.....	.....	...	67
12'45	83	83	49	16¼	17½	70	...	...	270	85	3	12'22'20	1'10'30	75	67
1'15	89	88	49	17	17	72	...	...	274	86	...	.....	.....	...	67
1'45	86	85	49	16¾	17¼	72	...	...	275	86	4	1'26'40	1.04'20	75	67
2'15	80	79	48	16½	16½	73	...	...	270	86	5	2'27'05	1'00'25	75	67
Average.....	...	...	...	...	...	73.1	...	6.024	...	...	...	.....	.....	75	

Net weight of a barrel of water (temp. 75°) = 439.4 pounds.

Duration of test..... 5 h. 12 m. 05 s.
Total weight of water collected, pounds..... 2,197.00
Total weight of water collected, per hour, pounds..... 422.38
Total weight of water collected, per hour, per I.H.P., pounds..... 70.12

Workshop engine; One-cylinder, double-acting, vertical engine, with slide valve. During test one small shaper and lathe were in use. No indicator cards taken.—Test No. 30, February 26, 1897.

Diameter of cylinder, inches..... 6
Stroke, inches..... 6

Test began at 2·35 P. M.

Time.	Steam pressure.		Vacuum.		Revolutions of engine.	Condensed exhaust steam.				Injection.
	Boiler.	Engine room.	Starboard engine room.	Port engine room.		Number of barrels.	Time full.	Time filling.	Temperature.	
P. M.							*h. m. s.*	*h. m. s.*		
2·30	93	90	19½	19	172	...	.....	.....	...	65
3·00	94	92	20	20	150	...	.....	.....	...	65
3·30	103	100	20	20	160	...	.....	.....	...	65
4·00	111	108	20	20	210	...	.....	.....	...	65
4·30	108	104	20	20	220	...	.....	.....	...	65
5·00	108	105	20	20	180	...	.....	.....	...	65
5·30	112	110	20	20	134	1	5·33·00	2·58·00	78	65

Duration of test..... 2 h. 58 m.
Total weight of water collected, pounds..... 439.21
Total weight of water collected, per hour, pounds..... 148 05

HEATERS.

The ship is heated by steam, and divided into four independent systems, as follows: forward, after, sick bay and cabin heaters. A separate trap discharging into the main feed tanks is provided for the return of each system.

In order to find the weight of steam used, the discharge from the trap of each system was (successively) temporarily diverted by means of a small hose, into the upper barrel shown on plate 2, and the amount determined as in other tests. It was necessary in addition, however, to make a slight correction on account of vaporization of part of the water thus delivered which escaped into the atmosphere. For example, with an average steam pressure of 32 pounds per gauge, and temperature of outside air of 55°, four barrels of water were collected from a test of the forward heaters, as follows:

1st barrel filled in 55 minutes 30 seconds; temperature of water, 188°.
2d barrel filled in 48 minutes 30 seconds; temperature of water, 190°.
3d barrel filled in 54 minutes 20 seconds; temperature of water, 185°.
4th barrel filled in 55 minutes 40 seconds; temperature of water, 185°.

Average.....53 minutes 30 seconds; temperature of water, 187°.

The weight of a barrel of water at 187° being 430.1 pounds, the apparent amount of steam used per hour was 482.35 pounds. But as the water discharging from the trap had a temperature corresponding very nearly to the pressure on the heaters, the vaporization is calculated to have been 34.8 pounds per hour, and hence the total steam used by the heaters, 517.15 pounds per hour.

Tests of the other heaters, similarly carried out, gave for the after system, 367.65; sick bay, 54.1, and cabin, 218, or a total of 1,156.9 pounds of steam per hour for all, the average steam pressure on heaters and temperature of outside air being about that stated in the test of the forward system.

CONCLUSION.

It has long been known that independent auxiliaries are extremely expensive in coal consumption, a fact which the foregoing tests amply confirm. This is, perhaps, more clearly seen from an examination of the data below, which were compiled on a passage between Gibraltar and League Island, Pa. During the period covered, seven days, the wing main engines were run continuously at 60 revolutions and practically under the conditions shown in Table II. An account was kept of the auxiliary machinery run and the time in operation.

Great care was taken to keep the water in the steaming boilers always at a constant marked height, and particular attention was given to insure accuracy in the record of coal expended.

No bad weather was experienced; the sea, as a rule, was smooth and the wind light. As the ship had been out of dry dock less than six weeks, the bottom was fairly clean.

The following are the important data recorded.

Date.	Calculated Displacement.	Knots run.	I.H.P. of main engine.			Coal used.	Remarks.
			Starb'd.	Port.	Total.		
1897.	*Tons.*					*Tons.*	
June 24	8,088	242.8	828.1	766.2	1,594.3	57 $\frac{671}{2240}$	Set clock back 19 minutes.
25	8,029	252.1	767.7	759	1,526.7	55 $\frac{840}{2240}$	Set clock back 18 minutes.
26	7,971	246.7	787.9	798.8	1,586.7	55 $\frac{1232}{2240}$	Set clock back 23 minutes.
27	7,912	252.5	795.3	784.3	1,579.6	57 $\frac{1232}{2240}$	Set clock back 20 minutes.
28	7,855	257.6	764.1	772.8	1,536.9	55 $\frac{840}{2240}$	Set clock back 21 minutes.
30	7,736	242.9	794.2	793.2	1,587.4	57 $\frac{1232}{2240}$	Set clock back 21 minutes.
July 1	7,676	248.7	764	767.4	1,531.4	57 $\frac{1232}{2240}$	Set clock back 20 minutes.
Average...	7,895.3	249	.....	.....	1,563.3	56 $\frac{1232}{2240}$	Set clock back 20 minutes.
Average (24 hours)...		245.5	.....	.....	.....	55 $\frac{1232}{2240}$	
Average per hour.....		10.2	.....	.....	.....	2 $\frac{735}{2240}$	

An estimate of the average weight of steam used per hour by the machinery in use is as follows.

	Total pounds of steam per hour.
Main engines, port and starboard	31,939.8
Condensation from main engine jackets, estimated	750
Condensation in main steam line, estimated	450
* Loss of steam from unavoidable leaks, estimated	480.8
Total	33,620.6

*Assumed as one-half the total loss of feed water per hour.

AUXILIARIES.

Main air and circulating pumps	2,641.9
Bilge pumps, (three)	1,291.2
Steering engine, estimated	450
Main feed pump	951.1
Pump for washing decks, ash hoists, galley coppers, shop engine, &c.	240
Dynamo	2,023.3
Flushing pump	275.7
Blower in evaporator room, and combined salt and fresh water pump for distilling plant	46
Steam to evaporators for distilling (average of 1,500 gallons per day)	651
Ship's ventilating blowers, (two after)	549.4
Ship's ventilating blowers, (two forward, 12 hours per day)	274.7
Ice machine	422.4
Miscellaneous (shifting of dynamos, &c.)	30
Condensation in auxiliary steam line, estimated	300
Total, auxiliaries	10,146.7

Hood's Merthyr coal was burned, there being three main double-ended boilers in use.

SUMMARY OF TESTS TO DETERMINE STEAM CONSUMPTION OF THE MAIN AN

Engine tested.	Number of test.	Dimen. of engine.				Double strokes or revolutions per minute.	Duration of test.	I.H.P. of engine from cards.
		No. steam cyls.	Cyl. diam.		Stroke (full).			
			Steam.	Water.				
			ins.	*ins.*	*ins.*		*h. m. s.*	
Main starboard engine	1	3	42 59 92	...	42	53	.....	610.85
Main starboard engine	2	3	42 59 92	...	42	60	.....	781.39
Steam cylinder, S. auxiliary condenser	3	1	8	...	12	33.20	5·21·00	1.232
Center circulating pump	4	2	10	*36	6	171.6	3·07·05	18.873
Center circulating pump	5	2	10	*36	6	90 0	2·49·30	4.104
Center circulating pump	6	2	10	*36	6	89 5	2·11·00	4.039
Starboard circulating pump	7	2	10	*36	6	82.0	3·28·20	2.017
Starboard air pump	8	2	16	31½	21	16.6	2·58·10	6 543
Center air pump	9	2	16	31½	21	15 2	3·02·42	25.181
Starboard water-service pump	10	2	7½	4½	10	40.9	2·59 00	1.039
Center fire and feed pump	11	2	12	8½	12	12.7	3 30·45	.7851
Center fire and feed pump	12	2	12	8½	12	37.3	1·45.30	6.412
Center fire and bilge pump	13	2	14	9	12	27.7	2·02 30	2.519
Main fire room feed pump	14	2	12	7½	12	11.02	2·23·20	8.828
Main fire room feed pump	15	2	12	7½	12	2.61	3·27·00	1.573
Forced draft blower engine	16	2	5	...	4	595·3	1·23·35	16.300
Ash-hoist engine	17	2	4½	...	4½	.....	50·00 24·00	.....
Dynamo engine, No. 1	18	2	10½	...	5	408.7	24·00 00	21.873
Dynamo engine, No. 1	19	2	10½	...	5	424 3 417.0	1·15·40 1·20·10	19 598 33.601
Dynamo engine, No. 1	20	2	10½	...	5	415.1	24 00 00	29.184
Dynamo engine, No. 2	21	2	10½	...	5	391.1 388.7	2·48·00 1·29·06	19 012 30 354
Dynamo engine, No. 2	22	2	10½	...	5	392.0 390.7	2 02·00 1·33·25	16.791 26.553
Dynamo engine, No. 2	23	2	10½	...	5	425.0 425.0	1·10 25 26·25	22.923 35.237
Dynamo engine, No. 3	24	2	10½	...	5	404.3 388.3	2·00·00 1·35·26	17.324 26.234
Dynamo engine, No. 3	25	2	10½	...	5	398.0 382.5	2·03·45 1·44·50	18.241 27.815
Dynamo engine, No. 3	26	2	10½	...	5	390.0	12·00·00	20.04
Flushing pump	27	1	8	9	12	31.7	3·11·15	1.421
Ventilating blower engine	28	2	4	...	3	277.5 404.3	1·59·50 52·30	....
Ice machine engine	29	1	7	...	10	73.1	5·12 05	6.024
Workshop engine	30	1	6	...	6	175.1	2·58·00	.....

* Two fans.

T

I.H.P. of engine from cards.	Condensed exhaust steam.		Remarks.
	Per hour.	Per I H.P. per hour.	
	Pounds.	*Pounds.*	
610.85	12,973.	21.237	Average of 7 tests.
781.39	15.959.	20.431	Average of 8 tests.
1.232	328.07	266.30	Knowles' combined air and circ. pump.
18.873	1,039 14	55.06	Approx. power developed on official trial.
4.104	310.86	75.74	Slide valve altered. Forward cylinder only taking steam.
4.039	402.33	99 61	After cylinder only taking steam.
2.017	252.63	125.28	I.H.P., main engine, 604.
6 543	1 195.70	182.74	I.H.P , main engine, 604.
25.181	1,969.90	78.23	Pump loaded by opening salt feed valve.
1.039	212.92	204.95	Pump used for flushing purposes.
.7851	250.19	318.68	Pump used for flushing purposes.
6.412	999.23	155 84	Pump used for washing decks.
2.519	430 43	170.87	Pump used on bilges.
8.828	806.94	91.41	Pump used for feeding steaming boilers.
1.573	382.00	242.85	Pump used for feeding auxiliary boiler.
16.300	1 262.30	77.44	Fire room closed in air tight.
.....	.....	.....	
21.873	2,695 60	123.27	Steam pistons water-packed, and bad fit to cylinders; cylinder bores rough and pitted.
19 598	1.737.1	88 64	New pistons with two cast iron packing rings in each; in use about 10 days.
33.601	2 293.2	68.25	
29.184	2.023.3	69 33	New pistons with packing rings in cylinders.
19 012	2.066.8	108 71	Water-packed pistons; cylinder bores rough.
30 354	2,550.7	84.03	
16.791	1.725.0	102.73	Water-packed pistons; cylinder bores rough.
26.553	2,250.0	84.74	
22.923	1.492.7	65.12	New pistons with packing rings; in use about 9 days.
35.237	1,989.2	56.45	
17.324	1,693.4	97.75	Water-packed pistons; fit cylinders closely. Cylinders in good condition.
26.234.	2,085.1	79 48	
18.241	1,488.8	81.62	New pistons with packing rings; in use about 4 days.
27.815	2,006.5	72.14	
20.04	1,962.5	97.92	Water-packed pistons.
1.421	275.7	194.02	
.....	274.65	.....	No indicator motion fitted.
.....	501.23	.....	
6.024	422.38	70.12	
.....	148.65	.....	No indicator motion fitted.

Tests Nos. 1, 2, 7, 8 and 14 were made at sea, the others while at anchor.

DIMENSIONS OF EACH BOILER.

Length, feet	20
Diameter, feet and inches	15–9
Furnaces, number (corrugated)	8
Furnaces, diameter (least), inches	40
Furnaces, diameter (greatest), inches	42⅞
Length of grates, inches	84
Tubes, number	1,268
Tubes, diameter, inches	2¼
Tubes, length between tube sheets, inches	87¾
Tube heating surface, square feet	5,540
Plate heating surface, square feet	861
Total, heating surface, square feet	6,401
Grate surface, square feet	186.7
Ratio G. S. to H. S.	1 to 34.29

RESULTS.

Average boiler pressure, by gauge	142
Coal consumed per hour, pounds	5,215
Coal consumed per hour, per square foot of grate, pounds	9.31
Refuse per hour, pounds	637.5
Percentage of refuse in coal	12.22
Total steam used per hour, all machinery, pounds	43,767.3
Pounds of water vaporized per pound of coal (average temperature of feed 85°)	8.39
Equivalent evaporation per pound of coal from and at 212°	9.89
Percentage of daily coal consumption to run main engines only	76.82
Percentage of daily coal consumption to run auxiliary machinery	23.18

Discussion.

P. A. Engineer W. M. McFarland, U. S. N.—I think we must all feel that the Society is to be congratulated upon this admirable paper, and I want to compliment the author on its excellence and on his perseverance in carrying out these trials during his regular duty and while the machinery was doing its ordinary work. This paper really "supplies a long felt want," for we had, until its appearance, absolutely no experimental data of the steam consumption of auxiliary machinery, nor, indeed, of that of the main engines, under the conditions obtaining on war vessels. I am not unmindful, of course, of the valuable *Ber-*

gen experiment nor of the classical work of the Research Committee on Marine Engine Trials of the Institution of Mechanical Engineers of Great Britain; but these were on merchant steamers, with a relatively very small amount of auxiliary machinery, and the circumstances are totally different.

When Prof. Hollis (then an engineer officer, U. S. N.) delivered his admirable lectures at the Naval War College in 1892, he was compelled to estimate the steam and coal consumption of the auxiliary machinery from indicator cards and as best he could. It is interesting to compare his estimate of 6 pounds of coal per I.H.P. per hour for many of the auxiliaries with the actual figures which Mr. White has found.

While we all doubtless believed that many of the auxiliaries were wasteful of steam on account of the conditions under which they have to work, probably no one imagined the figures to be as great as they are. In some respects, the data about the dynamo engines are the most remarkable, as showing what a great saving resulted simply from putting snap-rings on the pistons.

I would have been glad to see some data about the relative steam and coal consumptions when using two and then three boilers for about the same speed. Prof. Hollis called attention to the saving which could be effected by using the smaller number of boilers on account of reduced loss from radiation. During my recent cruise on the *San Francisco*, we had occasional opportunities to make such a comparison in a rough way, where at a speed of 7 to 8 knots two boilers were often used and one occasionally, and we found a decided increase of economy in using one boiler for these low speeds.

In conclusion, I may say that Mr. White deserves the thanks of the Society and also those of the profession generally for supplying this valuable information for which we have waited so long.

We are very fortunate, Mr. Chairman, in having with us to-day one of the foremost experts in auxiliary machinery in this country, Mr. Wheeler, of the Blake Pump Company. I know that he can give us a great deal of valuable information on this subject, and I trust he will favor us with his views on Mr. White's paper.

Mr. F. Meriam Wheeler, Associate.—This subject is a very important one, and the Society is to be congratulated, as well as Mr. White. To me it has for some time been of special interest. My attention was first called to it some years ago in the (August, 1890) JOURNAL of this Society when reading Chief Engineer Isherwood's interesting digest of the report of the experiments on the trial trips of the Hoboken Ferry boat *Bergen*. This report formed part of a paper by Col. E. A. Stevens and Prof. J. E. Denton, read at the annual meeting of the American Society of Mechanical Engineers, in 1889. It was shown that about 20 per cent. of the steam generated by the boilers was necessary to run the auxiliary machinery.

This subject of economy of the auxiliaries of marine engines has also been seriously discussed abroad. In Mr. White's introductory remarks he says that the object of making the tests of the auxiliaries on the *Minneapolis* was primarily to ascertain the consumption of steam of the dynamo engines, which was shown in the tests to be at the rate of over 123 pounds weight of steam per I.H.P. per hour. The methods employed by Mr. White and his associates in making the tests were certainly very good, and probably the best that could be arranged under the circumstances. No doubt the placing of the barrels for measuring the water of condensation some 16 feet above the auxiliary condenser which was used for making the test could not be avoided, but at the same time it placed on the air pump an undesirable load. This pump, which was a combined air and circulating pump of the Knowles make, upon which was mounted the Wheeler Auxiliary Surface Condenser, required at times as much as 266 pounds weight of steam per I.H.P. per hour. Now, there is no doubt this pump could have done the work with less than half this amount of steam for the following reasons:

The pump has a nominal stroke of 12 inches, and can be adjusted to make this, but the report says that the average stroke during the test was only 10¾ inches, thus entailing a loss from excessive clearance. The report also says that the air pump discharged at the rate of a little over 328 pounds of condensed steam (water) per hour, the speed of the pump averaging 33 double

strokes per minute. This is at the rate of a little less than 60 feet piston travel per minute. Now, a 10-inch pump cylinder (the diameter of this air cylinder) at this speed would deliver about 244 U. S. gallons per minute, or say 122,000 pounds per hour, which is about 371 times more than the amount of water actually discharged.

In elevating this water so far above the pump there was an unnecessary expenditure of power and steam. Now, to elevate the smaller amount of water, required as much power as the larger amount, because they had on the area of the air piston a pressure due to the head, say about 7 pounds per square inch. An indicator diagram taken from the steam cylinder of this pump would show a much higher terminal pressure than the initial in order to take care of this load on the air piston which it would not encounter until the extreme end of the stroke. Therefore, the steam cylinder had to be completely filled with steam at the terminal pressure in order to push this water out of the air cylinder to the height of 16 feet. It would, of course, have been better if the measuring barrels had been placed lower, but there was, no doubt, no other convenient place for arranging the measuring barrels. Engineers making tests on stationary plants do not realize the disadvantages and inconvenience with which marine engineers have to contend, especially in naval vessels, where the engine rooms are unusually crowded with machinery and piping.

Referring to Mr. White's tables, I notice that the independent (Blake) twin air pumps show considerable difference in their steam economy, the center air pump requiring 78.23 pounds per I.H.P. per hour while the starboard air pump consumed at the rate of 182.74 pounds per I.H.P. per hour. This latter amount is, of course, high, and was, no doubt, occasioned by unnecessary closure of the regulating valves, thus putting too much cushion on the steam pistons of the pump. Then, again, these steam cylinders are undesirably large for the air cylinders, as will be seen from the fact that the pump ran at a rate of about 16 double strokes per minute with only about 25 pounds steam pressure per square inch. Had these steam cylinders been 12 or 14 inches diameter instead of 16 inches, the economy would have been con-

siderably better, and if the pumps could have exhausted into the receivers of the main engine or into an auxiliary feed water heater a large amount of the rejected heat of the exhaust steam could have been saved.

In the matter of feed pumps, the 12x7½x12 vertical (Blake) duplex feed pump used for feeding the main boilers only required 91.41 pounds per I.H.P. per hour, while a pump of similar size used for feeding the auxiliary boilers required at the rate of 242.85 pounds per I.H.P per hour—a marked difference! Now, this great difference can be explained from the fact that the main feed pump was running at a speed of nearly five times the speed of the auxiliary feed pump. This is a very interesting point, and shows what great loss can be occasioned in pumps of small power when run at a low rate of speed. It is also possible that the loss from clearance was greater in the auxiliary feed pump, due to short stroke, a very common fault in direct-acting duplex pumps, from the very nature of their construction. It is very difficult, even in the best designs of duplex pumps, to get a full stroke on both sides of the pump, hence the loss from clearance is sometimes very great.

The circulating pumps, I notice, averaged about 75 pounds of steam per I.H.P. per hour, which is a very fair showing for a crank and fly-wheel engine of small caliber.

I also note, by Mr. White's record, that the dynamo engines, after they had changed the valves and angular advance of eccentric, were able to reduce the consumption of steam to a figure averaging a little less than the circulating pumping engine.

The ice-machine engine showed a very fair economy, viz: about 70 pounds.

As regards the main engine (which was the starboard engine), I note the average economy was between 20 and 21 pounds per I.H.P. per hour, and, considering the fact that the engine was developing hardly $\frac{1}{12}$ of its maximum power, I am surprised that it did so well.

Referring again to the economy of the independent air pumps, I should like to exhibit a study made by our expert engineer, Mr. Albert F. Hall, of some indicator diagrams taken from the steam

and air pump cylinders on the contractors' trial trip of one of the air pumps of the U. S. S. *Minneapolis*. (See Fig. 30.) The steam cards are rather odd looking, but this is peculiar to the system. It has frequently happened that engineers have misinterpreted these cards in the matter of the admission line. It will be noticed that the terminal pressure is much greater than the initial pressure, due to the fact that the maximum load on the air pump buckets occurs at the last part of the stroke. This explains somewhat the peculiar shape of these cards. There is no doubt that the regulating valves were not adjusted to the best advantage, but for all that the indicated horse power of these air pumps was only about $\frac{1}{6}$ of 1 per cent. of the horse power of the main engines according to the records on the contractors' trial trip of June 14, 1894. (See page 709 of No. 4, Vol. VI, of the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, dated November, 1894.) The cards also show these air pumps exhausting into the condenser, a very extravagant waste of heat. Had these pumps exhausted into the main engines or into a modern system of feed water heater, the actual amount of steam required for operating them would have been very much reduced. It has been shown by Mr. Hall, as nearly as possible with existing data, that the actual amount of steam required for the Blake system of independent air pumps is approximately the same as that required to operate connected air pumps.

Referring to the report of the test of the machinery of the British merchant steamer *Iona*, made by a committee of the Institution of Mechanical Engineers of Great Britain in 1890, it was shown that the engine (of the triple expansion type) indicated a little over 600 I.H.P., which, by the way, was about the power developed by the *Minneapolis* engines as reported in Mr. White's paper. In the case of the *Iona* the ratio of volume swept through by the low-pressure piston to the effective volume of displacement of the air-pump bucket per revolution (consequently per minute) was at the rate of 33.66 to 1. Now, the ratio as recorded in the contractor's trial trip of the U. S. S. *Minneapolis* above referred to was at the rate of 151 to 1—nearly five times as great. Assuming that the *Minneapolis*' air pumps

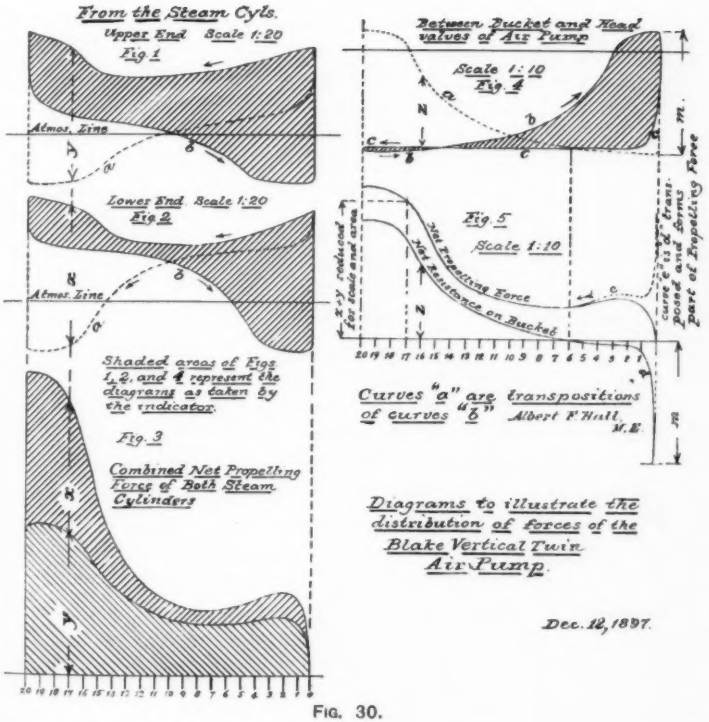

From the Steam Cyls.
Upper End Scale 1:20
Fig 1
Atmos. Line
Lower End Scale 1:20
Fig 2
Atmos. Line
Shaded areas of Figs 1, 2, and 4 represent the diagrams as taken by the indicator.
Fig 3
Combined Net Propelling Force of Both Steam Cylinders
Between Bucket and Head valves of Air Pump
Scale 1:10
Fig 4
Fig 5
Scale 1:10
Net Resisting Force on Bucket
Curve "c" is "a" transposed and forms part of Propelling Force
Curves "a" are transpositions of curves "b" Albert F. Hill, M.E.
Diagrams to illustrate the distribution of forces of the Blake Vertical Twin Air Pump.
Dec. 12, 1897.

FIG. 30.

required 100 pounds of steam per I.H.P. per hour, and from a study of many tests made abroad that a recovery in the exhaust steam from the air pump of one thousand B. T. U. per pound, is fair, and also assuming that the horse power of the attached air pump of the *Iona* is 2.4, and that the power required to run the Blake independent air pump is the same as that for connected pumps, Mr. Hall shows the actual amount of heat used by the plant, if the steam cylinders of the air pumps are arranged to exhaust into a feed water heater, to be 160,964.7 B. T. U., while the total heat used by the plant with attached air pump was given in the report as 161,100.09 B. T. U., a small margin in favor of the independent system.

In assuming that a connected air pump will do the work with the same power as an independent air pump, I am no doubt favoring the former, as owing to its higher rate of speed there must be a greater amount of friction. As a matter of fact I have never been able to find on record any test showing the actual amount of power required for a connected air pump. This can be readily explained, as it is very difficult to make such a test, whether on a marine or stationary engine.

I am very glad to find that the latest United States battleships and other United States vessels are being supplied with feed-water heaters for the auxiliaries. It adds but little care to the engineering force, is in the line of economy, and certainly of great advantage to the boilers, increasing their durability and facilitating steaming. It is a common thing to see the temperature of the feed water rise to over 200 degrees when the steam from the different auxiliaries exhausts into the feed water heater. The feed water entirely condenses the exhaust steam and carries the rejected heat so absorbed directly to the boilers. Loss of heat from radiation can be reduced to a minimum by carefully covering the pipes and heater.

I was very much pleased with the feed-water system they have in the transatlantic greyhound *Kaiser Wilhelm der Grosse*, recently put in commission by the North German Lloyd Steamship Company. The feed-water heater only occupies a small corner in the engine room, and yet it takes care of all the steam exhausted

from the auxiliaries, which include the independent (Blake) twin air pumps. The chief engineer (Mr. Baum) told me that the temperature of the feed water averaged between 200 and 210 degrees Fahrenheit.

In the old system, of exhausting the auxiliaries into the concondensers, nearly all of this heat is swept into the sea with the circulating water, which means millions of heat units going to waste annually, which means tons of coal and thousands of dollars.

Now, besides the use of the modern system of feed-water heaters for the auxiliaries, much heat can be saved by greater care on the part of the manufacturers of the different auxiliaries in the proportioning of the steam cylinders. No doubt smaller cylinders could be used, although there is a natural tendency to have them large enough to be able to run with low steam pressure in case of necessity. Then, again, many of these machines could be compounded without much increase of weight or space. Take, for instance, the case of the feed pumps which average from $\frac{3}{8}$ to $\frac{1}{2}$ of 1 per cent. of the I.H.P. of the main engines. Although it would increase the weight and space of these pumps to compound them, there could be saved at least 50 pounds of steam per I.H.P. per hour. Take the case of an engine developing 1,000 H.P.; the feed pumps would show a power of about 5 I.H.P. On the basis of the above saving, we should have 250 pounds of steam per hour, or 6,000 pounds, saved in a day of 24 hours' steaming. On a basis of boiler evaporation of 8 pounds water per pound of coal, this means nearly 800 pounds of coal saved per day—quite an item. In three days' steaming this is a little less than a ton of coal, which, by the way, would be about the weight of the feed pumps as arranged on the compound plan. As I remarked in the beginning, Mr. White's paper is very timely and a decidedly important communication, particularly in its giving facts and figures. The time has come when the builders of auxiliaries, particularly of steam pumps, must consider the refinements of steam-engine practice.

Mr. White deserves great credit in showing to the engineering profession that the engines of a ship can be tested under practi-

cally regular working conditions, and that it is possible to devise simple and inexpensive apparatus to test the machinery at intervals, and thus be able to detect undue losses.

Mr. Charles Ward, Associate.—I heartily concur in the judgment of the Council in awarding to this paper the gold medal. While there are many other very able and valuable papers worthy of much appreciation, this one embodies an amount of original research and painstaking investigation upon a matter which so far has been at best enveloped in much doubt and uncertainty. The resulting data are certainly startling. We have, of course, always known that the auxiliaries were fearfully extravagant in the use of steam, but who supposed that there were engines to-day using from 100 to 300 pounds of steam per indicated H.P. In the table before us giving the summary of tests to determine the consumption of steam of the main and auxiliary engines, we find there are thirty-four auxiliaries having in all fifty-two steam cylinders. Thirty-one of these engines were indicated, giving an aggregate of 471 horse power developed using collectively 56,049 pounds of water per hour, or an average of 119 pounds per I.H.P. Were these auxiliaries as economical as the main engines, 9,891 pounds of steam would have developed the same power. 46,158 pounds of steam or water being used per hour *more than is necessary* if the best conditions of economy prevailed. In other words, the data show that, at 8 pounds evaporated per pound of coal, 5,769 pounds of coal can be saved per hour.

It must, of course, be borne in mind that it is impracticable to realize this gain because of the complications which would follow the introduction aboard ship of high expansion engines for these numerous purposes, but one is forced to put the question: What are you going to do about it? Shall these numerous engines for as many purposes be brought together in fewer engines of a higher character and have a few central power plants capable of meeting similar wants with greater economy; or shall we design more economic engines for each individual condition even at the cost of slightly increased number of parts; or shall we have one more economical central steam plant developing power to be distri-

buted by electricity to the varied requirements in different parts of the vessel.

Col. E. D. Meier, Associate.—I have tried for some time to get the very data which Mr. White has supplied in his paper. I could find nothing so definite and accurate as given by Mr. White. Generally we can learn only the consumption of coal per H.P. hour of the whole vessel, and then have to make shrewd guesses at the evaporative efficiency of the boilers. Finally we have to guess how much of the steam is consumed by auxiliaries to arrive at the actual efficiency of the main engines. Mr. White has done us all a great service by his excellent paper.

P. A. Engineer Emil Theiss, U. S. N.—It has been subject of remark that in our naval service feed water heaters have not been used as extensively as their importance would seem to demand. It may be mentioned, however, that specifications of machinery for the *Iowa* and of the machinery of all ships since designed require feed heaters to be installed. The question of space available is very often decisive in this as in other machinery as to the type to be fitted. For example: in the case of the *Iowa* the feed water was heated by using the engine room auxiliary fire, feed and bilge pumps for circulating the feed water through feed heaters, the pumps drawing from the feed tanks and discharging back into these tanks. While this method of feed water heating is open to objections, it was about the best that could be adopted under the circumstances. As a further illustration of the extent to which space, or rather the lack of space, modifies design, may be instanced the *Chicago*, for which new machinery has been designed and built. Two heaters of the Normand type were purchased for this vessel, but of these only one could be installed, owing to the crowded condition of the machinery space.

With a view to utilizing to the fullest extent possible the steam consumed by the auxiliaries, provision is always made in our naval designs for admitting the auxiliary exhaust to the main engine receivers. Pipes and valves are so arranged that even

when the auxiliary exhaust line proper discharges to the main or the auxiliary condensers, the exhaust of the main air or of the main air and circulating pumps may be directed into the receivers independently.

Prof. W. F. Durand.—The author of this paper is to be congratulated on the opportunity and energy necessary to carry out the experiments herein described. The data presented are a distinct and valuable addition to those hitherto available on these subjects. It may be regretted, however, that the quality of the steam was not determined at the various engines tested. We cannot be too careful in remembering that we are dealing with *heat* engines, and that no accurate estimate of the performance, from a thermodynamic standpoint, can be made from a knowledge of the water required per I.H.P. per hour alone. The influence of this feature is readily seen if, for example, we compare the performance of two similar pumps, one located near the boilers and getting nearly dry steam, and the other located at a remote point and getting very wet steam. The water required per I.H.P. per hour in the latter case will be considerably more than in the former, but it is not fair to charge the pump with the difference. For the general purpose of an average estimate of the amount of steam required for the various auxiliaries, the quality is, of course, of less importance, since, under normal conditions, boilers may be depended on to furnish steam of about the same quality—say from 97 to 99 per cent. dry; but, for a satisfactory comparative estimate between various auxiliaries, or for a satisfactory independent estimate of their performance as engines, the quality is quite as necessary as any other feature, especially where there is likely to be a considerable difference in the quality at the various locations.

The data presented relating to the various reciprocating pumps are quite in line with previous data of the same character. Experiments which I have made on small, slow moving pumps of the nature of feed or general service pumps, have shown a consumption of 300 pounds and upward, and many more with which I have been conversant have shown similar results. The data

here presented bring out very clearly also the great increase in consumption with decrease of the amount of work done, or, expressed in other words, the relatively slight variation of *total* consumption with variation of work. In consequence, the consumption per unit of power may vary from 100 to 300 or 400 pounds per hour, depending simply on the conditions of use.

The consumption generally for the circulating and dynamo engines seems high, though in the former, the power developed was usually only a small fraction of that at which the best economy would naturally be shown, while in the latter, even with the new piston rings, the condition of the cylinders and valves was, perhaps, not favorable to good results. The results as a whole, are most interesting and valuable, as showing what may be expected in service conditions from auxiliary engines of this character.

The most interesting result of the series is, perhaps, that given for the main engine. It is to be regretted that no opportunity was presented for test under greater power. These engines develop about 7,000 I.H.P. each at maximum power with about seven expansions, and would probably have their maximum efficiency at not far from 4,500 or 5,000 with ten to twelve expansions. We have, then, a triple expansion engine working at about one-seventh or one-eighth the power for best economy, and giving a water rate of 20 to 21 pounds. This result I am inclined to consider as very good indeed, and, basing an estimate of the probable consumption at 5,000 I.H.P. upon such data as we have from smaller engines, it would seem fair to expect a value rather below 15 pounds.

One of the most important deductions from this result is that the excessive consumption for all purposes per unit of power in the main engine at reduced power, is in less degree due to a loss of economy in the main engine than we have been likely to suppose, and in greater degree due to the excessive consumption of the auxiliaries. The latter has always, of course, been understood in a general way, but I am inclined to believe that we have not in the past been accustomed to rate the main engine at greatly reduced power with an economy as high as the figures here given would seem to warrant.

With regard to the indicator card from the center circulating

engine, to which reference is made, but which is not figured in the advanced copy, I would say that if, as I suppose, the compression with poor vacuum shows a reverse curvature very near the end of the stroke, the explanation is presumably to be found in the excessive and rapid increase of internal condensation at this time. Under conditions presumably similar to those here existing, as shown by Dwelshauvers-Dery,* the internal condensation very near the end of the stroke may suddenly increase to an excessively large relative amount, often reversing the curvature of the compression line or even reducing it to a horizontal direction. This phenomenon disappears with good vacuum, since the high compression pressures necessary for its appearance are not then reached.

Prof. Wm. S. Aldrich.—The perusal of this valuable contribution raises many interesting points. While it is not possible to compare in detail different tests on the same auxiliary machinery, as all have not been reported in detail in the advance sheets, it will still be helpful to compare some of those which are so reported. This we have done for the center and starboard circulating pumps (tests Nos. 4 and 7) and for the center and starboard air pumps (tests Nos. 8 and 9).

TABLE I.—COMPARATIVE PERFORMANCE OF CENTER AND STARBOARD CIRCULATING PUMPS.

Auxiliary Tested.	No. of test.	I.H.P. developed.	Steam pressure.	Piston speed.	Water rate.
Center circulating pump.....	4	18.873	142.25	171.6	55.06
Starboard circulating pump.....	7	2.017	144.75	82	125.28

TABLE II.—COMPARATIVE PERFORMANCE OF STARBOARD AND CENTER AIR PUMPS.

Auxiliary Tested.	No. of test.	I.H.P. developed.	Steam pressure.	Piston speed.	Water rate.
Starboard air pump.....	8	6.543	137.4	58.1	182.74
Center air pump	9	25.181	113.1	53.2	78.23

* Revue de Mécanique, October, 1897.

In thus noting the comparative performance of the above groups of auxiliaries of the same size, respectively, it is to be particularly noticed how widely different such performances may be when determined under slightly different conditions of load, steam pressure and piston speed. In other words, auxiliary machinery identical in size and construction cannot be depended upon to give the same performance under same conditions.

The methods pursued in obtaining the steam consumption are slightly different in the two cases. Test No. 4 involved measuring the steam consumption of the steam cylinder of the starboard auxiliary condenser (noted in test No. 3), while test No. 7 was a direct measurement of steam consumption of the starboard circulating pump engine. Tests on the starboard and center air pumps, respectively, depend for their results upon the steam consumption measurement obtained by tests Nos. 7 and 3; that is, involve the water rates of other auxiliary machinery. This substitution method of making a clean consumption test was no doubt necessary under the conditions imposed. In general, however, it is only reliable when the water rate of the auxiliary substituted is that for a condition of operation identically the same in each case. Upon an examination of the powers developed respectively it appears that the power developed by an auxiliary when used to condense the steam from another auxiliary was not the same as when its own steam consumption was directly measured. This is the case in each of the instances noted where the auxiliary steam consumption has been substituted based upon a former direct measurement. Moreover, in the case of test No. 9, it has been assumed that the steam consumption of the starboard auxiliary condenser was the same as in test No. 3, notwithstanding that the power developed was not indicated.

To make reliable steam consumption tests which are thus dependent upon the substitution of a previously determined steam consumption, the latter steam consumption rates should be carefully determined with, let us say, one variable only, for instance, the I.H.P. developed, and the results plotted in a curve. That is to say, if one auxiliary condenser is to be used as auxiliary to an air pump, for instance, during a given test for the steam

consumption of the air pump, the auxiliary condenser should have its steam consumption determined for a range of values, and a curve plotted, from which the desired steam consumption of the condenser could be spotted off and properly substituted in determining the steam consumption of the air pump.

The steam consumption of the center circulating pump, test No. 4, appears to be abnormally low. The same may be said of the center air pump, test No. 9. Either this is the case or their respective counterparts of the same size have abnormally high rates. Of course, the low water rates of consumption are developed at the larger loads involved.

It is stated in relation to the entrained water in the steam pipes leading to these auxiliaries: "It is quite improbable that water (due to condensation or other causes) in the auxiliary steam line would reach any auxiliary engine, particularly as the pipe is well drained throughout its length by a system of drain pipes leading to three traps." In this connection it will be important to call attention to the paper presented by Prof. D. S. Jacobus, of the Stevens Institute of Technology, before a recent meeting of the American Society of Mechanical Engineers, on "The distribution of moisture in steam flowing in horizontal pipes." It is practically impossible to drain them. In order to secure commercially dry steam ($1\frac{1}{2}$ per cent. to 2 per cent. moisture only) an efficient separator should be properly located for each auxiliary. Then in testing for the steam consumption of that auxiliary the probable amount of entrained water in the admission steam could be easily allowed for, especially if a separator of known efficiency was used.

The presence of any moisture in admission steam will prove very detrimental to the effective and economic operation of such small units as make up the auxiliaries of naval vessels.

It is quite clear that improvements are imperatively required in all the types of auxiliary machinery reported upon in these valuable tests. In some cases it has already proven advantageous to obtain better economy in auxiliaries by suitable compounding. In other cases, as in certain lines of English practice, the boiler steam pressure is reduced from one-third to one-half through a pressure reducing and regulating valve, which at the

same time results in not only drying the steam, but slightly superheating it before admission to the steam cylinders of the auxiliary engine.

The whole report is admirable in showing what may be expected from similar installations if they are based upon the facts here presented. And while the tests are not made under heavily loaded conditions of the main engines, still they are sufficiently comprehensive to show the probable range of values to be allowed for in future installations. The percentage of steam used by auxiliaries is here again shown to be very high compared to the proportionate horse power which these auxiliaries develop.

Assistant Engineer C. K. Mallory, U. S. N.—The tests of machinery described in this paper, having been made under ordinary service conditions, on board a ship that had been in commission for nearly two years, should prove of much more interest and value than any shop tests of specially prepared engines.

There is little reason to doubt the accuracy of the results obtained, as all tests were carried out and data collected and worked up with great care.

If more experiments of this kind could be carried out on board ship, the result would undoubtedly be a decrease in the consumption of coal, both in port and at sea.

For example, in the case of No. 1 dynamo engine, as a result of the first test, the grooved pistons were replaced by pistons fitted with snap rings and the consumption of steam reduced from 123.27 to 69.33 pounds per I.H.P. per hour; thus effecting a saving of nearly 44 per cent.

By fitting the same type of pistons in Nos. 2 and 3 dynamo engines, we find a saving in the steam consumption of about 35 per cent. and 13 per cent. respectively.

From the experiments made with the slide valve on the forward cylinder of the center main circulating pump, we find a saving of nearly 24 per cent. in the amount of steam used, when compared with the after cylinder in which no changes had been made. In each case, the cylinders developed approximately the same horse power.

In a modern ship, the steam used by the auxiliary engines is an important factor, not only in port, but at sea, and is especially noticeable when steaming at low speeds; hence, any changes that will increase the efficiency of the auxiliaries should, if practicable, be made.

Comparative tests, made under various conditions similar to those carried out in the *Minneapolis* would furnish important data on this subject.

Chief Engineer George W. Baird, U. S. N.—The steam required to drive these independent pumps, as determined by Mr. White, appears large, but his methods are good and his deductions correct. The information is of great value. The pump builders, who have reckoned the power to drive their pumps in per centum of the main engine power, rather led engineers into using that comparison, which I always held to be misleading. I have already published some tests of auxiliaries, but my tests on a main air pump have not been satisfactory to myself, and therefore I do not expect it would satisfy the Society. I was not able to trap and weigh the steam used by the large independent air pump on board the *Dolphin*, but was obliged to calculate the weight of steam from the terminal cylinder pressures, which is but approximate. One great trouble with most direct pumps is in the shortening of their stroke when they are slowed down. The *Dolphin's* main independent air and circulating pump has a single steam cylinder, with a nominal stroke of 24 inches. I found it making 21½ inches; by changing the tappets I lengthened the stroke to 22½ inches; by speeding it up the stroke lengthened to 24 inches and the piston touched the cylinder head. At 10 strokes a minute, it made 21⅜ inches; at 16, 21⅞ inches; at 20 strokes it made 22¼, and at 24 strokes a minute it made 22½ inches. My figures showed this pump developed a horse power for less than fifty pounds of feed water, calculated from the cylinder pressures, and assuming the valves and piston to be tight.

The other "auxiliaries" on that fine vessel were piped to exhaust either into the main or donkey condenser. This enabled me to collect and weigh the condensed water, which I did as op-

portunity offered. I also provided tubs and a scale for weighing the feed water, which enabled me to make good tests, in port, of fuel, some of which have appeared in the JOURNAL.

During a fuel test (in port), which continued 24 consecutive hours, I had all the feed water weighed, the length of stroke of the feed pump measured and noted every quarter hour, and recorded, by a counter, the total number of strokes of the pump. The pressures and temperatures were recorded as incident to the fuel test. The feed pump was a Blake, single pump, $10 \times 6 \times 12$. Like most pumps with steam-thrown valve, it shortened its stroke as it was run slower. The mean length of stroke for the test was 8.683 inches, or a loss of more than 27 per cent. in stroke of piston. The actual piston displacement per hour should have delivered 8,193.18 pounds of water, whereas the actual weight delivered per hour was 8,162 pounds. I afterwards measured the slip, under the same pressures, and found 29 pounds of water per hour slipped past the piston, 2 pounds past the discharge valves at one end of the pump, or a total of 31 pounds. The pump had recently been overhauled, valve faces planed and scraped true, stems turned down, &c., and the water end had been newly packed. The test was made with one of the smaller boilers of the *Dolphin*, which required a very slow motion of the feed pump. I made another test in May, 1895, at sea, using two large boilers, when much more work was required of the feed pump.

Mean number of strokes per minute of feed pump	40.6
Mean revolutions of the main engine	59.14
Duration of test, in hours	10.
Actual stroke of pump, in inches	10.806
Displacement of water end of pump, per minute, cubic feet	7 056
Speed of piston in feet per minute	36.56
Mean indicated pressure on steam piston, pounds	22.25
Mean terminal pressure on steam piston, pounds	24.2
Mean indicated horses power developed in the steam cylinder	1.936
Mean indicated horses power developed by the main engine	978.8
Mean indicated horses power developed by the main air and circulating pump	10
Aggregate indicated horses power developed by the engine and its dependencies	990.736
Coal per hour, in pounds	2,668.9
Pounds of coal per I.H.P. per hour	2.69

Thus it appears that the air and circulating pump require but about 1 per cent. as much power as the main engine, while the feed pump requires about 1 per 500.

The space clearance at one end of the steam cylinder and valve chest of the feed pump is, cubic feet	.049
Ratio of clearance to piston displacement is	1 : 10.04
Length of feed pipe, in feet	84.5
Diameter of feed pipe, in inches	4
Number of quarter turns in feed pipe	8
Number of valves in feed pipe	3
Square feet of surface inside of feed pipe	86.16
Indicated steam pressure per square inch required to move the steam piston unloaded	1.495
Indicated steam pressure required to move the steam piston loaded	20.755
Ratio of area of steam to water piston	1 : 0.356
Net pressure per square inch against the water piston required to move it	58.529
Mean steam pressure in the boilers, pounds	54
Mean cubic feet of steam, per stroke, used in the steam cylinder, calculated from the pressure there	0.537
Pounds of steam, per hour, required to work the feed pump, calculated from the pressures	126.88
Pounds of steam per horse power per hour	65.5

When the main engine of the *Dolphin* was in operation everything was exhausted into the main condenser; consequently I could not trap and weigh the condensed water as I could from the donkey condenser.

The circulating pump of the donkey condenser is a No. 4 steam end and a No. 5 water end, Davidson pump; its air pump is a 10 × 6 × 12 Blake pump. I found it required 34.806 pounds of feed water per hour to operate the donkey circulating and air pumps, and 1,196.88 pounds to operate the dynamo engine, when its output was 6,652 watts (8.91 E.H.P.). As the donkey condenser was operated for the purpose of running the dynamo, in port, its work is properly chargeable to the dynamo.

The ship had a small crew, and had fairly good natural ventilation, and had there not been a dynamo on board, fires would no doubt have been hauled, in port, in warm weather, when the firemen would have had a rest, a chance to recuperate; but the comfort, indeed the luxury of the light afforded by the dynamo is tempting and extravagant. The publication of coal distribution

for the Navy last year showed that in some ships the total fuel used for lighting exceeded the total fuel used for propulsion.

As I put the first incandescent electric light into a Government vessel (1882), I have, naturally, watched with interest what it led to. With that first set no voltmeter nor ammeter was supplied. We judged by the appearance of a glowing lamp if it were up to candle power. The plant was for 120 lamps of 8 c. p. and 51 volts. I found it required 3.5 horses power to run the engine, belt and unloaded armature, and it required 6.9 horses power to glow 70 lamps. This was apparently a good economy, but as we had to estimate the normal candle power by the brightness of the glow, it is not claimed to be accurate. Thus

$$\frac{(6.9-3.5)}{70}746 = 36.2 \text{ watts per lamp, or } \frac{36.2}{8} = 4.52 \text{ watts per c. p.}$$

We afterwards transferred this plant to the Fish Commission station, at Woods' Holl, and installed a smaller engine and dynamo on board, but the latter was of about the same output as the former; *i. e.*, 60 lamps of 16 c. p. at 110 volts. We proposed using 10 and 16 c. p. instead of 8 c. p. lamps. This plant occupied much less room than the first. It required 2.58 net horses power to revolve the armature in the magnetic field, with 35 lamps of 16 c. p. glowing. The current generated was 2100 watts, or about 3.75 watts per c. p. Calculating the weight of steam from the indicated pressure in the cylinder, it appeared this little ($6\frac{1}{2} \times 8$) engine was producing an indicated horse power for 45 pounds of feed water per hour. It was an Armington & Sims engine, and the steam was expanded a little over four times; the boiler, at the low rate of combustion then employed, was vaporizing over 9 pounds of water per pound of coal.

The original generating set in the *Dolphin* (which was not installed by the engineers) was placed on the berth deck forward, and was the same size as that of the *Albatross* described above. But the wiring was very expensive, rubber covered and incased in lead. The magnetic field of the dynamo extended to the pilot house, and it was said on some courses deflected the compass about 12 points. This set was removed and another was

substituted with new wiring, but was placed in a space taken from the coal bunker, near the engine room, and far removed from the compasses; there was room in the engine room for it, and it should have been placed there. The engine was greatly inferior to the original dynamo engine, but the dynamo was multipolar and better than the original bipolar. The engine was connected directly to the armature, and was intended to run 750 revolutions a minute. The two steam cylinders were 5 inches in diameter of bore, and the stroke of the pistons was 3 inches. This set was in the vessel when I joined her in March, 1892; the electric plant was not in my department. Two lieutenants from the Navy Yard, and the "dynamo machinist" and his mate spent several days getting the plant in order, for it had been idle several months. They succeeded in getting it up to 720 revolutions a minute with 45 pounds of steam on our boiler gauge; the pressure was reduced somewhat at the engine, as there was a "pressure reducer" and two other valves and several turns in the pipe, and I thought it was doing very well. There appeared an output of 3,200 watts, sufficient to glow 50 lamps. About five months later (August 20, 1892) I was able to trap the condensed water from this dynamo engine and found 907.9 pounds per hour; at the time the volt meter showed 73 and the ammeter 56.5=4,124.5 watts. Mean steam pressure at dynamo engine was 61.66 pounds; vacuum, 3.16 inches; revolutions per minute, 614.16. This would be about 182 pounds of feed water per hour per electric horse power. The machine got worse with use, and we were obliged to keep increasing the steam pressure until we reached 70 pounds—all I was willing to carry in the old boilers of the *Dolphin*. In justice to the builders of that little engine, I will say it was an experimental engine, and they did not expect it to be installed on board a ship.

In July, 1893, there was a new plant substituted for the above. It is a directly connected machine of 200 amperes and 80 volts. Steam cylinders are 8½ inches diameter, and stroke of piston 6 inches. I succeeded in getting several tests of this machine, taking indicator diagrams, noting pressures, revolutions, volts, etc., and trapping and weighing the water condensed from the

exhaust. We were in fresh water in port, and I let all exhausts go into the air excepting that of the dynamo engine and the donkey circulator and air pumps; these latter, being determined by previous experiment, were subtracted, leaving the net water from the dynamo engine. I found it required 2.43 pounds per square inch of piston to run the engine and unloaded armature. In a run of 6 hours the mean boiler pressure was 40.21 pounds; vacuum, 6.25 inches; revolutions per minute, 374; indicated horses power, 10.41; volts, 80; ampères, 92.416. The horses power required to work the engine and unloaded armature and the friction of the load being deducted, there remained 10.184 net horses power applied to the generation of the current. The $(10.41 - 10.184) = 0.226$ horses power unaccounted for probably disappeared in the heating of the dynamo, mains and appliances. The condensed water, trapped and weighed, amounted to 952 pounds per hour, or 93.4 pounds per I.H.P per hour. As the lamps required 64 watts each, the above current would glow $\left(\frac{92.416 \times 80}{64}\right) = 115$ lamps. This was a larger load than the average, and, as you all know, the lower the load factor the more expensive will be a unit of light. The maximum load I ever saw on the machine (when there was a ball on board) was 11,520 watts, or about 180 lamps. The machine would carry 16,000. I have taken these figures from my note book, where there are more tests recorded.

Chief Engineer W. F. Worthington, U. S. N.—The writer is entitled to thanks for having taken so much trouble to bring the subject under discussion to notice in such a forcible, even startling manner. There can be no doubt that the condensation in the pipes of steam cylinders of auxiliary machinery on shipboard is enormous. There is abundance of circumstantial evidence, such as leakage of water about the stuffing boxes, etc., to show this. The amount of steam used by the auxiliaries is also great. On the U. S. S. *Castine*, I observed that by turning the auxiliary exhaust into the receiver the number of revolutions of the main engines was invariably increased about ten, *i. e.*, from 120 to 130,

8 per cent. In the same manner on the U. S. S. *Montgomery* the revolutions invariably increased about eight, *i. e.*, from 90 to 98, about 9 per cent. This was simply the work left in the steam after the auxiliaries had rejected it. I am not prepared, however, to accept the figures in the tables as being even approximately correct. I consider that to get fairly reliable figures three things are indispensable:

First, that the engine under test be examined immediately before, or, better, after the test to see if the valves and pistons are tight at the time. (This appears to have been done only in one case, that of the center circulating pump engine.)

Second. A separator must be provided close to the steam cylinder to collect condensed water that may be running in a stream, unmixed with steam, down the steam pipe.

For example, on a test I recently made at Clemson College, of an engine used to run the machinery in the steam laundry, the amount of water from the exhaust was 310 pounds per hour to run a mangle, and only increased to 333 pounds, when three other machines were connected up, increasing the power used about five times, showing that much the largest part of the water was due to condensation in the pipes. This was further shown by stopping the engine and observing how quickly the vertical part of the steam pipe filled with water. In this case, as in the case of some of the auxiliaries on the *Minneapolis*, the steam pipe to the engine was connected at the side of the auxiliary steam pipe, so that one might suppose that most of the condensed water would go straight on rather than turn a right angle. Such water may or may not be properly charged to the engine under test, according to circumstances.

Third. A separating calorimeter (such as Carpenter's) must be used to test the percentage of water mixed with the steam. Ordinarily, this would not be much, but on occasion, might amount to a great deal. The mere fact that a certain number of pounds of water are collected from the exhaust, is not a sufficient basis for even a rough estimate of an engine's performance. Under the circumstances, it is useless to speculate on the cause of the enormous differences in the amount of water used per I.H.P., varying

from 55.06 in one case to 318.68 in another. I would like to hear if the writer has any suggestions to make on these points and also if the manufacturer of the Knowles and of the fire and feed pumps have any data which would throw light on the subject. I think many will agree with me that it would be most desirable to have every auxiliary machine tested for efficiency, before it was installed on a ship, and to furnish the ship with a copy of the test made under different conditions. It often happens that the expenditure of coal for auxiliary purposes varies greatly on two sister ships and also varies largely from time to time on the same ship, upsetting all calculations with regard to steaming radius. Often, this cannot be traced to the coal, firemen, or condition of the boilers, and it is impracticable at the time to examine all of the auxiliary machinery to look for leaks. If all the facts were known about each machine, it is quite probable that a slight change in the method of running it might make a considerable difference in the cost.

P. A. Engineer W. W. White, U. S. N.—(Reply after the meeting.) While no calorimetric tests were made of the steam for the data recorded in the tables of this article, I feel perfectly safe in asserting that practically dry steam was furnished by the boilers in use in all cases. I do not wish to be understood, of course, as implying that there may not have been one or possibly two per cent. moisture in the steam, but I am inclined to regard the latter figure as a maximum.

Referring to the tests of the starboard engine, recorded in Tables I and II, I may mention that these represent only a small number of the tests made. Many others, at the same revolutions of the engine and approximately the same power, with different boilers in use, showed practically the same consumption of water per I.H.P. per hour noted in the tables. For instance, for the data in Table II, three main boilers of the after group (Plate I) were in use. Some days afterwards, and with the engine running under identically the same conditions, six tests, with three boilers of the forward group under steam, gave an average result per I.H.P. per hour, only differing by .039 pound

from that in Table II. On another occasion, under the same conditions, four tests were made, which gave for an average 21.9 pounds of water per I.H.P. per hour. At first I was at loss to understand the reason for the increase. Upon investigating, to make sure that nothing but the exhaust from the main engine entered the condenser, I found the "bleeder" valve on top of the condenser leaking slightly, although closed hand-tight; this was apparent from the peculiar noise in the neighborhood of the valve. When this was closed by a wrench the water consumption per I.H.P. per hour, as ascertained by four additional tests, showed 20.51 pounds, thus checking very closely previous tests.

I appreciate that erroneous results might very well be obtained in tests of the main engine by the method used. If the boilers under steam are forced or the steam pipe not well drained, the probability of error is great. These conditions, however, were carefully guarded against during the tests covered by Tables I and II.

Experience at sea on the *Minneapolis* proved that the best economy was secured when the consumption of fuel per square foot of grate in use did not exceed about ten pounds. When the power developed required a much higher rate of combustion, the steam furnished was apt to be wet. This was clearly shown on one occasion when, with the wing engines running at 53 revolutions per minute, and two boilers in use (Table I), an attempt was made to increase the revolutions to 70, for the purpose of securing a test at a higher power. To accomplish this it became necessary to put on forced draft. While it was possible to thus increase the power, it was very evident that the steam was not dry, and at intervals small quantities of water carried over to the engines. The results of the tests were, therefore, of no value.

AUXILIARY MACHINERY.

With reference to tests of auxiliary machinery, and particularly with regard to condensation which occurs in steam piping, I think the assumption of such water collecting at the bottom of a horizontal steam pipe is a fact well established by numerous experiments. Professor Jacobus, in an article "On Determining

the Moisture in Steam," published in the "Stevens Indicator" for October, 1897, says in part: "In a horizontal pipe of sufficient length, and for the velocities of steam which occur in ordinary practice, the water collected at the bottom and ran along in a small stream, which could be wholly drained out in most cases by means of a small drip pipe leading from the bottom of the pipe."

It has been stated, on page 13, that the auxiliary steam line (horizontal) was drained throughout its length by a system of pipes leading to three traps. I may say further, in this connection, that these drains ran below and parallel to the auxiliary steam line, tapping into the bottom of it at short intervals. Under conditions ordinarily prevailing on board ship—that is, with the ship down by the stern—one trap, which was located in the center engine room, would probably have been ample to secure perfect drainage of the entire auxiliary line, since water of condensation would naturally gravitate to the drains leading to this trap. As a matter of fact, this particular trap, judged from the frequency of discharge, effectually accomplished this.

The three traps referred to were of the Dinkel pattern, and there was never uncertainty as to their working condition, especially the center engine room one, which could be heard, when discharging, at a great distance from its location. As an assurance of these traps being kept in efficient condition, their working parts were examined weekly.

The *Minneapolis* was provided with two auxiliary boilers of the dimensions given on page 49. Experience proved it was impossible to force one of these sufficiently to produce steam required for the usual auxiliaries run in port. It was customary, therefore, to use both when it became desirable or necessary to use the auxiliary boilers at all. Usually, and because it was more economical, one of the main boilers was kept under steam for port purposes, but only four of the eight furnaces were fired, the remaining four (wing) being closed tightly to prevent the entrance of air. All tests of auxiliary machinery in port, except test No. 26, were made with steam on one of the eight main boilers. Of these, the six after were alike, the dimensions of each being stated on page 57.

The two forward boilers only differed from the others in being of a slightly less diameter (15 feet 3 inches) and length (18 feet), with corresponding decrease of total heating (4,894.6 square feet) and grate (168 square feet) surface. The amount of contained water to the steaming level was, very nearly, 42 and 37½ tons respectively.

Before these tests of auxiliary machinery were undertaken, and with one of the main boilers under steam, the daily port expenditure of coal averaged 9½ tons. As a result of the change in the dynamo-engine pistons, and of altering the discharge pipes from certain traps to lead to the bottom of the feed tanks, instead of near the top as originally installed, by which means the temperature of the feed water was raised considerably, and, also, of several other changes, suggested by these tests, the average daily expenditure of fuel was reduced to 6⅝ tons. If the fuel could have been burned with the same economy in one, or both, of the auxiliary boilers, or in any one of the main boilers, the average weight per square foot of grate per hour, at the rates mentioned, would have been as follows:

Boiler.	Square feet of grate in use.	Average coal per square foot of grate per hour, pounds.	
		At rate of 9½ tons per day.	At rate of 6⅝ tons per day.
One auxiliary boiler	32	27.71	19.32
Two auxiliary boilers	64	13.85	9.66
One main boiler (2 forward)	84	10.56	7.36
(6 after)	93.4	9.49	6.62

From an examination of the above, and keeping in view the large reserve power of a main boiler when used for port auxiliary purposes, I think the conclusion irresistible that practically dry steam was furnished to the auxiliary steam line. This being the case, the next question to be considered is, whether water due to condensation in this 5-inch pipe could have reached any auxiliary in operation. Since, as before stated, the drainage of

this pipe was exceedingly well provided for, it is unnecessary to dwell upon this point.

The vertical connections from the auxiliary steam line to the different auxiliary machines were always direct, of comparatively small length and diameter, and, as was the case with all steam and exhaust piping, well lagged. While there was no provision for draining these small connecting pipes, the error which might occur from condensation therein during any test must have been inappreciable, particularly as they were heated to normal working conditions before recording data of the test.

In considering the results of these tests, it is immaterial, in my opinion, that these connections were, in several instances, made to the side of the auxiliary steam line rather than to the top, although the latter is always to be preferred when practicable. Of course, from improper drainage or water being suddenly carried over from the boiler, a side connection might often be the cause of inefficiency and possible damage to an auxiliary in operation.

I do not agree with Chief Engineer Worthington when he says, in reference to these tests of auxiliary machinery, that "the mere fact that a certain number of pounds of water are collected from the exhaust is not a sufficient basis for even a rough estimate of an engine's performance."

To verify their accuracy, I may say that many of the tests were repeated. For example, test No. 27, of the flushing pump, was made with the after starboard boiler in use for auxiliary purposes. Previous to this (November 14, 1896), and with the forward port boiler under steam, a test of this pump, under the same conditions, was run by Assistant Engineer C. K. Mallory, U. S. N., who, I may further add, rendered valuable assistance in almost all tests and in working up data. This test extended over a period of about four-and-a-half hours, during which time the steam cylinder of the flushing pump and the steam cylinder driving the starboard air and circulating pumps, were indicated every half hour. The flushing pump ran at a slightly greater number of double strokes, and the I.H.P. exceeded, by a small amount, that recorded in test No. 27. The result obtained was 199.02 pounds of water

per I.H.P. per hour. Comparing this with that given in test No. 27 (194.02 pounds), and remembering that the condensed exhaust steam collected in this test included also that from the steam cylinder working the starboard auxiliary air and circulating pumps (and which had to be deducted from the total collected in accordance with the power developed by that steam cylinder, test No. 3), the two results, under the circumstances, show a close agreement. It is to be noted, too, that in one case the boiler under steam was quite near the flushing pump, and in the other, widely separated.

Other cases might be cited, such, for instance, as experimentally determining the weight of water contained in the starboard feed tank between marks, which involved the accuracy of test No. 8, the starboard main air pump. With the starboard engine running at a constant speed and power, a series of tests were made to ascertain the average interval of time required to fill the tank between marks when only the exhaust from the main engine entered the condenser. Afterwards, the air pump exhaust was shifted from the auxiliary line to the main condenser, its speed kept constant, and the average interval found with this added. Then, having previously determined the steam consumption of the air pump, the capacity of the tank between marks was readily calculated from the average intervals thus obtained. Taking into consideration the condenser leakage per unit of time, the capacity of the feed tank between marks, as determined in this way, only differed by 30 pounds, or one-half of one per cent. from that by weighing water into the tank.

As the apparatus for testing the auxiliaries remained in place for about five months, it often became desirable, during that time, to operate the starboard auxiliary condenser for port purposes. No change was made when this was found necessary, but, of course, on such occasions the water of condensation, instead of being delivered directly to the feed tank, ran through the two barrels shown in plate 2. This permitted a check to be made on many of the tests by timing a few barrels and noting the auxiliaries in use, without further trouble than manipulating the valves on the bottom of the barrels.

An analysis of the results of these auxiliary tests will hardly bear out the comment by Mr. Worthington that, "under the circumstances, it is useless to speculate on the cause of the enormous differences in the amount of water used per I.H.P., varying from 55.06 in one case to 318.68 in another."

In the first place, it is important to remember that the former figure was obtained from a test of a two-cylinder simple engine, working at nearly full power, driving a pair of centrifugal pumps, the latter from the steam cylinders of a duplex pump at a small fraction of its maximum power. The conditions of using steam are so essentially different in the two cases that, unless an enormous difference were shown, it would be convincing proof of the inaccuracy of the tests.

As all the main circulating pump engines were exactly alike, the results may be summarized as follows:

Test No.	I.H.P.	Steam per hour per I.H.P. Pounds.
4	18.873	55.06
6*	4.039	99 61
7	2.017	125.28

* After cylinder only taking steam.

The conclusions to be drawn are,—First, that these engines are expensive in the consumption of steam. An examination of indicator card No. 5 gives a clue to the reason, and test No. 5 illustrates what saving is to be expected from an alteration in the valves. Second, tests Nos. 6 and 7 serve to emphasize the well-known fact that where any steam engine is worked at a lower power than that for which designed, the consumption of steam per I.H.P. per hour increases as the power decreases. This is also true of pumps, only in a more marked degree, as will be apparent from recapitulating the results of tests of the duplex pump, from which Mr. Worthington quotes:

Test No.	I.H.P.	Steam per hour per I.H.P. Pounds.
12	6.412	155.84
11	.7851	318.68

Had this pump worked up to a power approaching its maximum, no doubt the water per hour per I.H.P. would have decreased materially, probably to 100 pounds or slightly less.

It may be remarked here, in regard to the dynamo engines, which all show a comparatively large consumption of steam under all circumstances, that their design precluded the possibility of alteration to make them economical. By fitting piston packing rings, much was accomplished in that direction, but another fatal fault was unpacked piston valves, which unquestionably permitted steam to escape into the exhaust without doing work. On account of the arrangement of bridge pieces in the valve chambers, it was impossible to fit snap rings to the valves.

PROPULSIVE POWER.

By James N. Warrington, Esq., Associate.

In a paper published in the Journal of the Society in May, 1894,* the writer put forward a formula for the approximate calculation of the propulsive power of ships. Since that time several new ships of the Navy have undergone speed trials, and the results generously given out by the Navy Department invite comparison. An explanation is needed to render such comparison intelligible.

Briefly, the formula is an expression of the well worn proposition that the resistance of a ship is mainly due to friction and wave making. The method of calculating the friction requires no special mention. For the determination of the power absorbed in wave making the conception is employed of a representative series of trochoidal waves having a speed of advance equal to the speed of the ship, and requiring for its propagation a power equal to that of all the waves actually produced by the ship. The power of a series of trochoidal waves has been formulated by Mr. A. W. Stahl, U. S. Navy.† By the omission of a factor, the value of which is nearly constant in this application, a simple expression is obtained for the power absorbed in wave making.

It is clear that the conceived series of waves will be truly representative only when the several series of actual waves are propagated independently of each other. Any interference by one series in the formation of another will so affect the resistance as to put the formula in error. Model experiments indicate

* Journal American Society of Naval Engineers, Vol. VI., p. 259.

† Transactions American Society of Mechanical Engineers, Vol. XIII, p. 454.

that such interference occurs at quite moderate speeds, but the effect upon the resistance is very small; so small that in the progressive trials of ships it is masked by influences concerning which we may only surmise. At higher speeds, however, the effect is more pronounced, and places a limit upon the application of the formula.

As originally presented, the formula contained a wake factor, which is here omitted as an ill-advised complication.

Let P_f = power absorbed in friction.
P_w = power absorbed in wave making.
C_1 and C_2 = constants.
L = length of immersed body in feet.
A = area of immersed midship section.
S = area of wetted surface.
V = speed in knots of 6,080 feet.

Then $P_f = \frac{SV^{2.83}}{C_1}$; $P_w = \frac{A^{\frac{1}{2}}V^7}{C_2L^3}$; $P_t = P_f + P_w$.

THE FRICTIONAL CONSTANT.

In table V are given values of the frictional divisor proper to a clean painted surface in sea water, both for friction only and also for friction increased by seven per cent. The former, under C_f, are R. E. Froude's values transcribed from Table III, page 222, of Taylor's "Resistance of Ships and Screw Propulsion." The latter values, under C_1, are employed in the applications which follow. The exponent of V has been increased from 2.825, as given by Froude, to 2.83, in order to allow for the effect of eddies and air resistance.

APPLICATIONS.

In a paper on "Speed Prediction and Progressive Trials," read before the International Engineering Congress at Chicago in 1893, Archibald Denny gave some curves of model resistance. The curves of sheet VII, page 17, of that paper are reproduced in Figure I in full lines, and the resistance, as calculated by the formula, is shown in dotted lines. The constants are those proper to fresh water, but it will be observed that the frictional

divisor has been diminished by about seven per cent. in order to bring the calculated curves up to the trial ones for the low speeds at which the wave making is practically *nil*. The values of the constants are $C_1 = 27{,}610$ and $C_2 = 404$.

Table I contains the calculated and actual powers of the progressive trial of the U. S. S. *Bancroft*.* The constants are $C_1 = 33{,}700$ and $C_2 = 392$. This value of C_2 is nearly the salt water equivalent of the value obtained from Denny's curves. In the analysis of the engine power the constant resistance of the engine is taken at two pounds per square inch of the aggregate area of the low pressure pistons. All efficiencies are presumed to be constant.

Figure II represents the progressive trials of the U. S. Gunboats *Marietta* and *Wheeling*,† the full lines being the trial curves while the dotted line is calculated. The same comparison is given in Tables II and III. The influence of wind resistance is here very clearly shown. The two boats are described as being alike in hull and engines, and hence both curves might have been obtained equally well from either. Mr. Bieg states, "The runs of the *Wheeling* at low speed were made during a comparative calm, while those of the *Marietta* were made in a rather fresh breeze. At the higher speeds the conditions were exactly reversed." The values of the constants are $C_1 = 33{,}670$ and $C_2 = 392$.

In Table IV are given the results of the full power trials of a number of ships of the Navy, together with the calculated power P_t and the ratio $P_t \div$ Net *H.P.* The constant engine resistance is taken in all cases as two pounds per square inch of the *L. P.* pistons. C_2 is taken at 392 in all cases.

Table VI gives values of the several powers of V which are required in the calculation.

OTHER CONSIDERATIONS.

In the case of ships having quasi-parallel middle bodies and having ends for which the proper value of C_2 is known, the

*Journal American Society of Naval Engineers, Vol. V, p. 384.

†Journal American Society of Naval Engineers, Vol. IX, p. 641.

length, L, may be taken as that of the combined entrance and run. In this case the whole length of immersed body may be represented by tL; t being a factor.

By means of the formula certain problems may be easily solved. For example, the length which will make the power a minimum for a given displacement and speed; and also for a given area of midship section and speed. For these problems, reference is made to the appendix of the original paper.

TABLE I.—U. S. S. *BANCROFT.*

$$\frac{P_t}{\text{Net H.P.}} = 0.537$$

V	4.85	6.80	8.60	10.40	11.95	13.30	14.52
P_t	16.03	42.58	86.53	160.60	264.41	403.75	589.67
Net H.P.	29.85	79.30	161.13	299.07	492.38	751.86	1,098.08
I.H.P.	52.57	109.30	198.63	344.07	544.88	811.86	1,165.58
Trial I.H.P	65.00	110.00	200 00	340.00	540.00	815.00	1,170.00

TABLE II.—U. S. GUNBOAT *MARIETTA.*

$$\frac{P_t}{\text{Net H P.}} = 0.52$$

V	6.815	8.587	10.594	11.994	13 045
P_t	51.33	105.47	218.70	356.29	511.87
Net H.P.	98 71	202.82	420 57	685 17	984 36
I.H.P.	126 08	237 57	463.89	734.67	1.039.58
Trial I.H P.	132 40	261.68	477.96	735.33	1,040 47

TABLE III.—U. S. GUNBOAT *WHEELING.*

$$\frac{P_t}{\text{Net H.P.}} = 0.52$$

V	7.306	9 437	10.395	11.333	12.674
P_t	63 85	145 74	205.52	285 67	454.64
Net H.P.	122.80	280 27	395.23	549.36	874.31
I.H.P.	151.84	317.87	437.83	596 96	928.10
Trial I.H.P.	150.94	310.67	466.01	654 82	1,003.21

TABLE IV.—SHOWING THE VALUE OF THE RATIO $\frac{P_t}{\text{Net H.P.}}$

$$P_t = P_f + P_w \qquad P_f = \frac{SV^{2.83}}{C_1} \qquad P_w = \frac{A^{\frac{1}{2}} V^7}{C_2 L^3} \qquad C_2 = 392$$

The constant engine resistance is assumed at 2 pounds per square inch of the L.P. pistons.

Data are for trial conditions.	Length of immersed body. L	Area of immersed midship section. A	Area of wetted surface. S	Displacement in tons. D	Cylindrical co-efficient. $\frac{35D}{LA}$	$\frac{L}{\sqrt{A}}$	Propelling engines only. I.H.P.	Net H.P.	Speed in knots. V	$\frac{V^2}{L}$	C_1	$\frac{P_t}{\text{Net H.P.}}$	Reference. JOURNAL AMERICAN SOCIETY NAVAL ENGINEERS.
Bancroft	189.5	277	6,150	832	0.555	11.38	1,170	1,102	14.52	1.11	33,700	0.535	Vol. V, p. 365.
Machias	193	324.6	6,816	1,067	0.596	10 71	1,794	1,693	15.46	1.24	33,700	0.536	Vol. V, p. 846.
Castine	193	324.6	6,816	1,067	0.596	10.71	2,128	2,025	16.03	1.33	33,700	0.535	Vol. V, p. 846.
New York	384	1,350	30,814	8,480	0.572	10.45	16,947	16,019	21.00	1.15	34,300	0.561	Vol. V, p 613.
Olympia	344	969.5	24,300	5,586	0.586	11.04	16,850	16,068	21.68	1.37	34,220	0.533	Vol. VI, p. 241.
Columbia	412	1,120	27,590	7,350	0.557	12.31	17,991	16,882	22.80	1.26	34,380	0.590	Vol. VI, p. 1.
Minneapolis ...	412	1,125	27,660	7.387	0.557	12.28	20,366	19,250	23.07	1.29	34,380	0.550	Vol. VI, p. 702.
Brooklyn	402.6	1,225	29,500	8,150	0.578	11.50	18,248	17,309	21.91	1.19	34,300	0.544	Vol. VIII, p. 741.
Marietta	174	349	7,250	991	0.570	9.31	1,040	985	13.04	0.98	33,670	0.520	Vol. IX, p. 641.

TABLE V.—THE FRICTIONAL DIVISOR FOR SALT WATER AND A SMOOTH PAINTED SURFACE.

L	Friction only.		Friction plus 7 per cent.	
	C_f	Log. C_f	C_1	Log. C_1
10	28,050	4.447929	26,210	4.418545
20	30,870	4.489509	28,850	4.460125
30	32,240	4.508440	30,130	4.479056
40	33,200	4.521092	31,030	4.491708
50	33,820	4.529135	31,600	4.499751
60	34,280	4.535037	32,040	4.505653
70	34,640	4.539633	32,380	4.510249
80	34,900	4.542879	32,620	4.513495
90	35,090	4.545213	32,800	4.515829
100	35,280	4.547559	32,970	4.518175
120	35,550	4.550866	33,230	4.521482
140	35,750	4.553243	33,410	4.523859
160	35,900	4.555154	33,560	4.525770
180	36,020	4.556593	33,670	4.527209
200	36,100	4.557554	33,740	4.528170
250	36,310	4.559969	33,930	4.530585
300	36,510	4.562396	34,120	4.533012
350	36,630	4.563859	34,240	4.534475
400	36,760	4.565327	34,350	4.535943
450	36,880	4.566800	34,470	4.537416
500	37,010	4.568278	34,580	4.538894
550	37,130	4.569761	34,700	4.540377
600	37,260	4.571250	34,820	4.541866

TABLE VI.

V	Log. V	Log. V^2	Log. $V^{2.83}$	Log. V^7
1	0.000000	0.000000	0.000000	0.000000
2	0.301030	0.602060	0.851915	2.107210
3	0.477121	0.954243	1.350252	3.339847
4	0.602060	1.204120	1.703830	4.214420
5	0.698970	1.397940	1.978085	4.892790
6	0.778151	1.556303	2.202167	5.447057
7	0.845098	1.690196	2.391627	5.915686
8	0.903090	1.806180	2.555745	6.321630
9	0.954243	1.908485	2.700504	6.679694
10	1.000000	2.000000	2.830000	7.000000
11	1.041393	2.082786	2.947142	7.289751
12	1.079181	2.158362	3.054082	7.554267
13	1.113943	2.227886	3.152459	7.797601
14	1.146128	2.292256	3.243542	8.022896
15	1.176091	2.352182	3.328337	8.232637
16	1.204120	2.408240	3.407660	8.428840
17	1.230449	2.460898	3.482171	8.613143
18	1.255273	2.510546	3.552419	8.786904
19	1.278754	2.557508	3.618874	8.951278
20	1.301030	2.602060	3.681915	9.107210
21	1.322219	2.644438	3.741879	9.255533
22	1.342423	2.684846	3.799057	9.396961
23	1.361728	2.723456	3.853690	9.532096
24	1.380211	2.760422	3.905997	9.661477
25	1.397940	2.795880	3.956170	9.785580
26	1.414973	2.829946	4.004373	9.904811
27	1.431364	2.862728	4.050760	10.019548
28	1.447158	2.894316	4.095457	10.130106
29	1.462398	2.924796	4.138586	10.236786
30	1.477121	2.954242	4.180252	10.339847

Fig. I

MODEL RESISTANCE CURVES

LENGTH L	MIDSHIP SECTION A	WETTED SURFACE S	CYL. COEF.
11.95	0.9565	23.96	0.5673
"	0.7840	20.83	0.5451
"	0.6121	17.75	0.5227
"	0.4575	14.96	0.5012

Full lines by Tank Experiment
Dotted " " Formula

$$R = \frac{33000 \times (P_f + P_{sc})}{\text{Speed in ft. per min.}}$$

$$P_f = \frac{SV^{2.82}}{C_1} \qquad P_{sc} = \frac{A^{\frac{3}{2}} V^7}{C_2 L^3}$$

$C_1 = 27610$ $C_2 = 404$

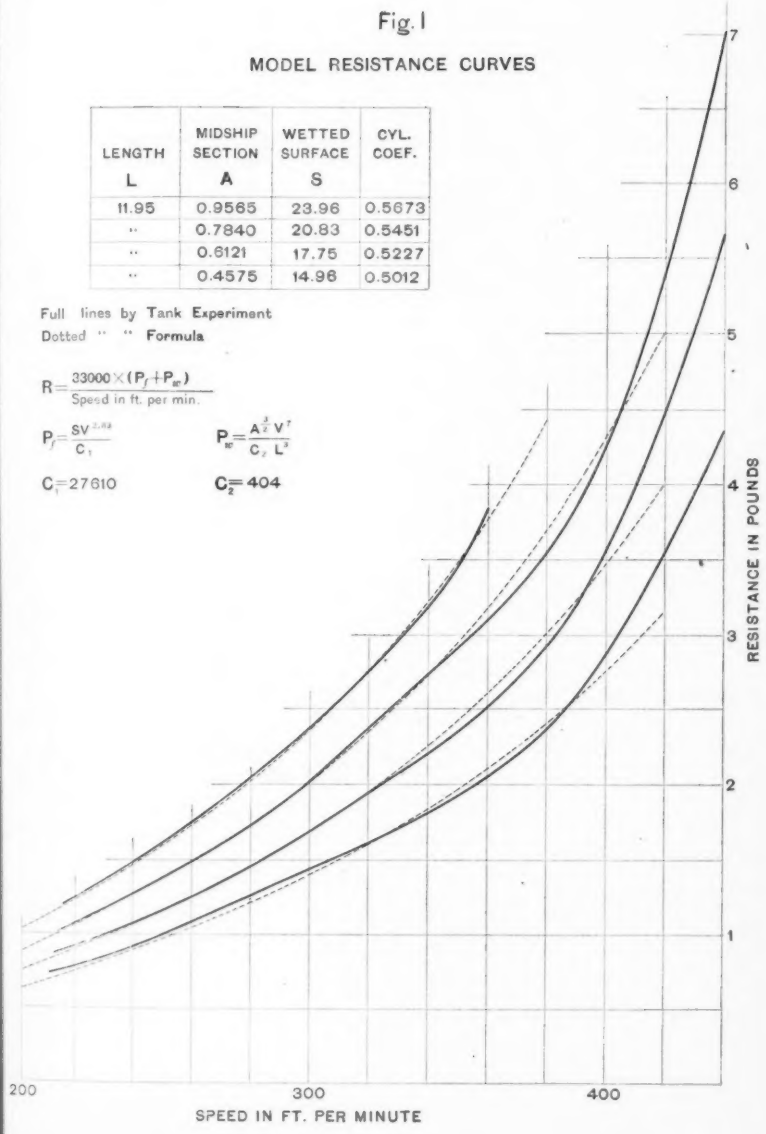


Fig. 2

PROGRESSIVE TRIAL CURVES

U.S. GUNBOATS

Marietta and Wheeling

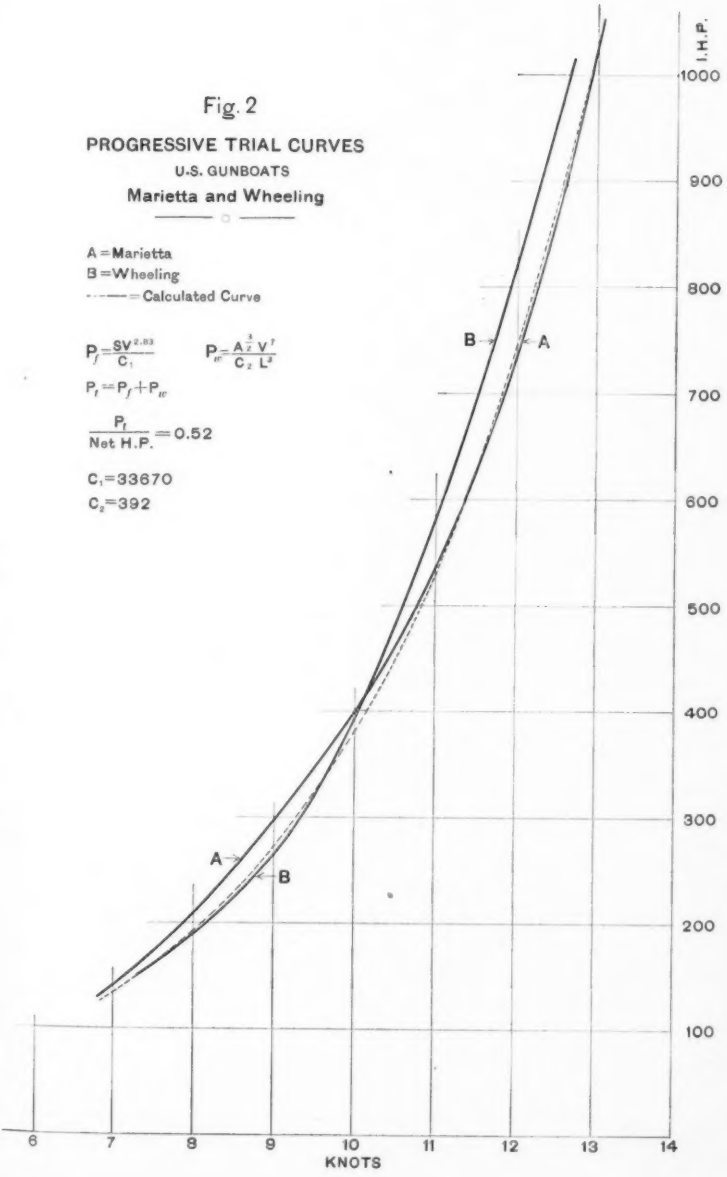
A = Marietta
B = Wheeling
- · - · - = Calculated Curve

$P_f = \frac{SV^{2.83}}{C_1}$ $\quad P_w = \frac{A^{\frac{3}{2}} V^7}{C_2 L^2}$

$P_t = P_f + P_w$

$\frac{P_t}{\text{Net H.P.}} = 0.52$

$C_1 = 33670$
$C_2 = 392$



CENTRAL POWER PLANTS ON BOARD SHIP *VS.* DISTRIBUTION OF POWER.

By Professor Wm. S. Aldrich, Member.

There are certain inherent advantages in centralizing the generation of power for any given purpose. In almost all cases the original sources of power for the purposes under consideration are the steam engine and boiler plants. In all cases of the use of steam it has been long known and practiced, as well in its generation as in its utilization, that greater economy is to be effected by a centrally located plant. However, when it relates to the transmission and distribution of power from such central steam plant we are at once confronted with the claims of three principal rivals, namely: compressed air, water pressure, electricity. In particular, on board ship we believe there will be reduced cost of installation, increased economy of operation, fewer men required in operation and management, if all the power required for the several auxiliaries should be developed in a single power plant. The same principle has been fully worked out in the mechanical equipment of modern office buildings, hospitals and other public institutions, department stores and isolated plants.

Only one working fluid is actually required for all cases of power distribution. If we are permitted for a moment to speak of electricity after the manner of the old school and to consider it as a working fluid, then it is quite clear that all of the auxiliary machinery on board a Naval vessel may be operated by any one of the working fluids—steam direct from the boilers, compressed air, water pressure or electricity. Moreover, only one working fluid is actually required.

All the various operations now carried on by so-called "mixed systems" of power distribution on board ship can be effectively

reproduced and satisfactorily performed by suitable motors and mechanisms driven by any one of the working fluids above noted. Primarily, of course, all power for such distribution is to be derived from steam engines. Therefore the efficiencies of transformation of energy in each of the above cases should not be left out of consideration. It is not our present purpose to enter the discussion respecting such efficiencies of transformation involved in converting steam power into compressed air, water pressure or electricity.

For all the purposes, therefore, for which power may be required on board ship it may be developed:

(1.) In a centrally located plant. This should, of course, be as near the battery of boilers and main engines as possible, placed in the same or adjoining water-tight compartments, and all below the protective deck.

(2.) At points where the power is to be utilized. In this case several power generating plants require to be located in different parts of the ship, being most suitably installed at or near the centers of distribution. In this case, however, it must be remembered that steam from the boilers is the original source of energy for the distributive development of power. All prime movers for any system of power generation on board ship are and will continue for a while to be of the various types of simple and compound steam engines.

Should the power required at any point be developed elsewhere in a central plant and transmitted to that point for direct utilization? Or should such power be generated by a steam engine on the spot and further transformed into compressed air, water pressure or electricity, as may be required for application at such point? It will be seen that the whole problem resolves itself largely into a question of the distribution of power. The distances for such distribution are so short on board ship that there is practically no necessity for considering any of the so-called line losses in power transmission work. The transformation losses, however, are vitally important. In any case these should not exceed, if they should ever be found to equal, the present losses from mechanical friction alone in the many auxil-

iary steam engines scattered throughout the ship. Losses incident to the transformation of energy vary slightly with the load, but in a different manner for each of the working fluids noted. Again, such losses, if confined to a central power plant, should not even approach those of similar losses in the transformation of energy in the different power generating steam engines scattered throughout the ship. The question of the storage of energy is not so important on ship board as might, at first sight, appear. Compressed air probably admits of the readiest storage for use on Naval vessels, with the least disastrous results from shot and shell. A storage battery for electricity or a hydraulic accumulator are practically out of the question. The former requires no system of storage for use on ship board; the latter almost imperatively requires such storage for maintained distribution of energy.

Looking for a moment at the steam engine required for such a central power plant, it will be found to be advantageous to subdivide the plant into generating units. Representative types of compound engines now so extensively used for such subdivision are chiefly of the self-contained type. There would be little use for single or paired simple engines for such a central plant.

If steam power is converted into electricity for all of the operations required on board ship, it will be interesting to note different characteristic features of such installation. It would be beyond the range of the present paper to investigate fully the comparative advantages and disadvantages of each of the systems of power distribution—steam, compressed air, water pressure and electricity. The present purpose is merely to have in mind some definite system for a discussion of the steam generating plant required, should all of the power be thus developed in a central plant.

Consider a central power plant made up of compound condensing steam engine units, each a duplicate of the other, with all parts of the same size and respectively interchangeable, and certain advantages will at once be apparent, namely: the plant may be operated at all times in such manner that each engine is loaded to its full normal capacity; variation in load may be met by throwing

in or out one or more of such steam engine units. The ranges of power for variations of load will in no case be so great on any one engine as in the several steam engines used to drive the scattered auxiliaries.

In the matter of equalizing the load on such a power plant driven by duplicate steam engine units, it is seen that the conditions are ideal and extremely favorable when applied to electric generation. The plant may be operated at a nearly uniform load day and night, respectively. The electric light load at night may be offset by additional electric motor load during the activities of the day. Also, certain pumping machinery can be operated at any time by electric motors during the day or the night, so that these may be thrown in or out to compensate for otherwise large variations in load. One in charge of such a central electric power and lighting plant on board ship would be able to so operate it and obtain a load curve which would be the admiration and envy of central station managers on shore. Station indicators would so indicate terminal conditions on the circuits that the most efficient operation of the plant would be obtained at all times.

It is quite impossible to treat of this question without further treading upon the debatable ground respecting the merits and demerits of the different methods of power distribution. In all cases, however, the following economic features should be carefully weighed for any given or specified service: cost of installation; running expenses, involving pay of attendance, cost of coal and water, oil and waste; depreciation and repairs.

In this connection it is important to notice the results of Mr. H. A. Foster's analysis of the tests of twenty-two different power plants.* These included manufacturing establishments, electric light stations, pumping engines, etc. Plants above 200-horse power show a remarkable uniformity in fixed charges, namely: interest on first cost, depreciation, taxes and insurance. The operating expenses gradually decrease in plants from 200 to 1,000

* Transactions of the American Institute of Electrical Engineers, Vol. XIV, "Variations in the cost of steam power," by Mr. H. A. Foster. Paper presented at the annual convention, July 28, 1897.

horse power, above which capacity the operating expenses seem to remain remarkably uniform and quite irrespective of load variations. The large electric stations supplying many smaller industries are scarcely affected by the instantaneous load changes in one or more of these particulars.

Other features of the electrical system are its thorough adaptability to all of the work required on board ship, its extreme flexibility, and withal it is possessed of the best system of distribution by means of insulated wires in conduits making it the least liable to derangement in action. The distributing mains may be safely and securely run through water tight bulkheads and compartments. The transmission line losses are practically negligible for the short distances under consideration. The distribution losses on the several branch circuits alone require detailed consideration. The direct current is, of course, to be used in all cases. In such a system it is possible to secure a higher maintained efficiency of operation of the plant than any other system, and this is really the point to be desired in any such installation. In the electric system, also, it is possible to control with known certainty distant motors for various auxiliaries, and such control may be from one central point.

The electric system alone admits of such subdivision of the generating plant into equal and interchangeable engine-dynamo units. The advantages of this on ship board are too apparent to require discussion.

There is not now an auxiliary on board ship which cannot be operated with certainty, efficiency and economy by electric motors. All pumps, fans, blowers, hoists, shifting and steering gear, turret gear and gun mounts may be so operated, and are every day reaching towards this system of operation. The same may be said of the air compressors required for refrigerating purposes.

Boiler feed pumps can now be far more economically driven by electric motors than by any of the present types of steam engine cylinders usually attached to the same. They may be set at any time for various rates of feed, and with certainty, from a switch in the boiler room. Air pumps and condensers may be similarly operated, and have their speed and vacuum controlled by simple

switch in engine room. All low-lift suction pumps, bilge pumps, etc., may be very efficiently operated by either geared or direct connected slow-speed electric motors. In fact, the whole of such electric lighting and power plant installation on board ship may be operated at all times at the most economical and nearly uniform loads, and at uniform steam pressures and speeds for the dynamo engines. This cannot be said of the steam engines operating any other kind of auxiliary machinery or operating any other system of power distribution. The inherent advantages of the electric system are chiefly due to the facility of transformation of electrical energy, especially in view of the fact that all such transformations (with or without load variations) in no special manner affect the efficiency and economy of the steam engines driving the electrical generators.

Concerning the effect of variations of load in modern electric power plant engines, it is interesting to note that Messrs. A. G. Pierce and R. S. Hale state of the Boston Edison stations: "as a matter of fact, the steam per indicated horse power in our two 200 units holds within 12 per cent. over a range from one-quarter up to full output."*

While the above has been noted in the case of large engine dynamo units, it is none the less true that remarkably uniform rates of steam consumption may be obtained in smaller compound direct connected units, as has recently been noted in the JOURNAL of our Society.† Two questions are primarily involved in a general consideration of this problem: economy of installation and efficiency of operation. Respecting the first, it is possible to obtain refinements of design and economic arrangements of installation not yet reached in electric power plant by adopting heat-unit specifications and subsequent contract trials upon this basis. At least, the efficiencies, economies, guarantees and contracts now being realized in modern high duty pumping

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* Quoted by Mr. F. R. Low, Report of Committee on Data, National Electric Light Association, Buffalo Meeting, June 8, 1897.

† JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.—"High Speed Self-Lubricating Steam Engines," by Alfred Marcom. Vol. IX, No. 4, November, 1897.

plants should be much more nearly approached in electric power plants. The special features of such heat-unit ratings have been presented by the author in two recent papers before the American Society of Mechanical Engineers,* from which, as an example of such ratings, the table on the next page has been taken, being compiled from the report of the Committee on Data of the National Electric Light Association, Buffalo meeting, June 8, 1897.

The writer further pointed out in the above paper that some very uneconomical engines have produced remarkable results in point of economy of operation and efficiency of installation. The best of engines may be poorly operated on the one hand, and the whole plant badly arranged on the other.

We enter as strong a plea as any one for the most economical engine for electric power plants; but we wish to add a further requirement, that there should be economic installation and efficient operation to produce the best all round results in the course of a day, a month or a year. Should the Government require heat-unit specifications and contract trials for the electric light and power plants installed on board Naval vessels, much better results would be shown than those heretofore attained, of which the performance of the dynamo engines of the U. S. S. *Minneapolis* as reported in another paper at this meeting of the Society, may be taken as a fair example. In this case there are three duplicate sets of electric generating units. Each set is driven by a pair of simple engines, 10½ inches diameter, 5-inch stroke, at speeds ranging from 382 to 425 revolutions per minute, and developing from seventeen to thirty-five I.H.P., under normal working range of loads. Under the best conditions reported (when these engines were tested after several days' run with new pistons and packing rings), the steam consumption ranged from 56 to 88 pounds per I.H.P. per hour. Similar tests have been previously required, it is true, but the contract trial has not been based upon a guaranteed performance stated in heat-unit ratings of kilowatt hours per

* "Transactions of the American Society of Mechanical Engineers," vol. XVIII, No 733, "On Rating Electric Power Plants on the Heat-Unit Standard;" and vol. XIX, No. 766, "Notes on Rating Electric Power Plants on the Heat-Unit Standard" (second paper), by Wm. S. Aldrich.

TABLE I.—SHOWING EXAMPLES OF RATING ELECTRIC POWER PLANTS ON THE HEAT-UNIT STANDARD, REDUCED FROM 1897 REPORT OF COMMITTEE ON DATA OF NATIONAL ELECTRIC LIGHT ASSOCIATION.

Station No. in 1897, Report N. E. L. A.	Pounds feed water per kilowatt hour, at best efficiency.	Temperature of feed water. Fahrenheit.	Steam pressure (gauge). Pounds per square inch.	Total heat B. T. U. in feed water per pound.	Plant ratings. Kilowatt hours per 1,000 pounds water, at best efficiency.	Plant ratings. Kilowatt hours per 1,000,000 B. T. U., at best efficiency.	Type of engines.	Rating at best efficiency, water per I. H. P. hour.	Method of driving dynamos.	Dynamos daily output. Watt hours.	Kind of service. Daily.
1	2	3	4	5	6	7	8	9	10	11	12
4	23.50	...	160	.....	42.60	.....	Vertical, triple expansion, four-valve.	15	Direct Connected.	200,000,000	Incandescent, 24 hours.
14	26.65	120	115	1,100.0	37.55	34.14	Tandem, compound condensing. Double tandem, compound non-condensing. Cross-compound.	17.5	Belted to jack shaft. To Dynamos.	124,000,000	Arc and incandescent, 24 hours.
1	37.50	212	125	1,009.5	26.70	26.45	Vertical compound, non-condensing, four-valve.	25.8	Direct Connected.	13,600,000	Incandescent, 24 hours.
10	38.10	...	112	.....	26.30	.....	Compound condensing. Simple non-condensing.	28.5	Belted to dynamos.	3,400,000	Arc and incandescent, 24 hours.
2	39.30	212	125	1,009.5	25.50	25.26	Horizontal cross-compound condensing. High speed, single-valve, automatic.	25.7	Belted to dynamos.	1,400,000	Incandescent, 6 to 12 hours.
7	45.00	180	135	1,053.20	22.20	21.08	Simple non-condensing. Compound non-condensing.	28.0	Belted to dynamos.	13,000,000	Incandescent, 24 hours.
8	45.00	...	160	.....	22.20	.....	Cross-compound condensing. Tandem compound.	28.0	Direct connected. Belted to dynamos.	12,400,000	Arc and incandescent, averaging 17 hours.
5	47.70	208	125	1,013.50	21.00	20.72	Simple non-condensing. Compound non-condensing.	29 1	Belted to dynamos.	15,600,000	Arc and incandescent, 24 hours.
9	53.27	140	120	1,080.70	18.80	17.39	Single-acting compound condensing. Simple automatic non-condensing.	28.0	Belted to dynamos.	2,700,000	Arc and incandescent, 24 hours.

1,000,000 British thermal units. That recently reported in the JOURNAL of our Society * by Chief Engineer G. W. Baird, U. S. N., marks an advance in the right direction. Should such a performance of electric power plants be determined in accordance with and based upon ratings on the B. T. U. standard, it would be of great value for establishing engineering precedent in reference to the power required by the auxiliary machinery driven by electric motors.

As a further example of the values to be obtained when rating the performance of an electric power plant on the heat-unit standard, the following table has been prepared:

TABLE II.—PERFORMANCE OF THE ELECTRIC LIGHTING PLANT OF THE GOVERNMENT HOSPITAL FOR THE INSANE, AT WASHINGTON, D. C., BASED ON THE HEAT-UNIT STANDARD, FROM RESULTS REPORTED BY CHIEF ENGINEER GEORGE W. BAIRD, U. S. N.

	Small plant.	Large plant.
Date of making test	Nov. 19, 1896.	Dec. 1, 1896.
Number of Kilowatts per hour	57.20	108.90
Pounds of feed water pumped into the boilers per hour	2,285.00	4,481.70
Mean temperature of feed water, in degrees Fahrenheit	129.9	125.9
Steam pressure in boilers, in pounds per square inch above atmosphere	93.41	92.33
Total heat in one pound of steam, being the heat required to raise one pound of feed water from its temperature to that of the steam at the boiler pressure and evaporate it into steam at that temperature (Kent's Tables)	1,085.7	1,089.5
Plant ratings:		
(1) Kilowatt hours per 1,000 pounds of feed water	25.03	24.30
(2) Kilowatt hours per 1,000,000 British thermal units supplied to the system	23.06	22.30
Engines, cross-compound, rope-belted to dynamos.		
Diameters, inches	10½ and 16½	13 and 20½
Stroke, inches	12	15
I.H.P. developed, when loaded	103.64	197.07

Wherever power is to be transmitted or energy distributed, even for such short distances as occur on board ship, and in vary-

* JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.—"The construction, Installation and Performance of the Electric Lighting Plant at the Government Hospital for the Insane, at Washington, D. C." Vol. IX, No. 2, May, 1897.

ing quantities for many different sized units, the most expensive of all methods is that by the use of steam as the working fluid. While it has been found in many cases desirable, for some purposes, to have a combination or mixed system for distributing power from a central station on board ship, it can scarcely be said to be in accordance with the best engineering practice.

For all operations involving rotary motion, continuous or intermittent, uniform or variable, unidirectional or reversible, electricity stands pre-eminently at the head. For certain very definite reciprocating movements with fixed time or distance limits, hydraulic mechanism, or electric motor driven mechanism with hydraulic control, has proven best suited. For reciprocating movements requiring a cushioning effect, compressed air is better adapted. For efficient service in any case, however, compressed air requires to be reheated and used expansively in a cylinder with all parts and mechanisms practically the same as in the steam engine.

No one system of power transmission can well be advocated from a central station until a thorough trial has been made of one system throughout any given ship. This has been pointed out by Mr. George W. Dickie, in a recent paper before the American Society of Mechanical Engineers, on "Auxiliary Engines and Transmission of Power on Naval Vessels."* Mr. Dickie states: "in the present state of the art of transmitting power to all parts of the modern warship, it is not possible to compare one method with another as a whole, and from actual experience, there being no one ship with a complete system of transmission from a central generating station of one type to compare with another ship having an equally complete system from a central generating station of another type."

There are certain inherent considerations in the use of any working fluid, as well as practical details for its distribution, which set the limits for each of the respective systems. Steam, electricity and compressed air will stand up to the work and permit a considerable overloading of generators and motors. The

*Transactions of the American Society of Mechanical Engineers, Vol. XIX, No. 761, "Auxiliary Engines and Transmission of Power on Naval Vessels," by Geo. W. Dickie.

hydraulic system, on the other hand, is limited and must be installed throughout large enough for the maximum capacity ever likely to be required of it. Again, it is clearly of little avail to transmit power by water or compressed air and have to transform it again into any particular mechanical movement or any required source of energy whenever and wherever such may be required on board ship. Light, heat, ventilation, power for rotary and reciprocating movements, water for sanitation and fire service, and refrigeration are all required to be amply provided for, and such services efficiently maintained, on board every Naval vessel. That merchantmen have led the way in some instances in the application of electrical distribution for several of the requirements above noted may serve to indicate the possibilities in store for similar central electric light and power plants to be located on Naval vessels. Electricity will, directly or indirectly, provide for all of the above services on ship board, and in an economical manner, with the exception of distributing heat. This, of course, will remain to be supplied by steam distribution or the forced circulation and ventilation of the hot-air system. For quickness and certainty of action as well as almost instantaneous application of the motive power applied, electricity scarcely has a competitor, especially when the power is to be applied in an accumulative manner. An instance of this is the recent contract for the operation of the turrets of the battle ships *Alabama* and *Illinois* by electric motors, following in the wake of the cruiser *Brooklyn*, similarly fitted out with electric gear.

WATER TUBE BOILERS.

By Darwin Almy, Esq., Associate.

As water tube boilers are being more extensively used in marine vessels of all descriptions, they are destined in the near future to take the place of all fire tube boilers. This may seem to many to be a very broad assertion; nevertheless, I believe it to be true.

When we look back and see the many different designs of water tube boilers that were built before 1880, (and, so far as I am able to learn, every one of them was a failure), and then look at the great stride that has been made in the building of them and the success that they have attained in the past ten years, who can tell what the next five years will bring forth?

In speaking of the early water tube boiler I refer to both land or stationary and marine boilers, but the boiler that I refer to since 1880 is entirely for marine use.

There were illustrated in various publications prior to 1880 the designs of water tube boilers that embodied every principle that is found in those that are in use at the present time. They were built with straight tubes, bent tubes and coils. The tubes were placed at various angles from horizontal to perpendicular. Some of them had their downflow tubes inside, others outside of the jacket, and some without downflow tubes. They were also furnished with various forms of separators.

In looking over these designs and analyzing them, it is very easy to see why they failed. One of their greatest defects was the lack of provision for the expansion of the tubes forming the heating surface. In those where they provided for the expansion they were lacking in heating surface. Other marked defects were in the circulation and inability to furnish dry steam, or else so dry that it was extremely superheated. They also used tubes of too large diameter. (These defects are characteristic of some of the water tube boilers that are being placed in vessels

even at this time, and which will in a short time demonstrate this fact.)

In order to make a successful water tube boiler, it must have a provision for expansion in every direction and a perfect circulation. When I say perfect circulation, I mean that there must not be some other way that the water can go to escape from the extreme heat of the furnace; if there is such a course, the water is sure to take it rather than to go the way which is intended.

The circuits must be short and direct, so that there will be no steam pocket formed in the tube in contact with the furnace heat. The flow of gases should be equal over the whole heating surface, whether the boiler is being worked at a low or high duty. It should give dry steam; *i. e.*, not over one or two per cent. moisture.

It should not give superheated steam, as that burns out the packing around piston and valve rods, cuts the valve seats and cylinders, necessitating the use of oil to prevent cutting.

Oil thus introduced coats the condenser tube and the heating surface of the boiler, affecting its evaporation, shortening its life, and causing greater loss than is gained by the extra duty performed by superheating the steam.

The heating surface must be thick enough to insure durability and to prevent rupture if the metal should become overheated by careless usage.

The boiler must be easily accessible for repairs and so designed that a defective part of the heating surface can be removed or stopped off without removing any of the jacket or being obliged to cut out some other tube in order to renew a defective tube.

It must carry an even water level; *i. e.*, not over two to three inches change of level from working full power to stop, and there should be no more change when the vessel is rolling.

A water tube boiler that will fill such conditions will take the place of the fire tube and will have the advantage of occupying much less space, one-third to one-quarter the weight, greater economy, safety and durability.

In the present water tube boiler there is nothing new in principle, but the improvements have been in the form, material and

details of construction, and the many patents that are issued are on that particular form and description given in the patent specifications.

It is often said that some water tube boilers have too many joints, especially screw joints, that come in contact with the furnace heat. This is a mistaken idea, which has been proved by many years of continual usage. It does not make any difference whether it is a screwed or an expanded joint. So long as the boiler has a perfect circulation of water through all the tubes and the expansion is provided for in every direction, the joint is no more liable to leak than the tube itself. If it is lacking in these two factors, even if it is a solid drawn tube, the boiler is doomed to failure.

The diameter of the tube is another factor which plays a very important part in the construction and the life of a boiler. Large tubes that come in contact with the furnace heat can never be successful, for the reason that the expansion cannot be overcome.

The smallest tube that can be used has not been determined; that will depend on the length of the circuit. From my observation, I am satisfied that the tubes which form the fire box should not, under any conditions, exceed 12 feet in length or 2 inches external diameter. If so, the boiler is of short life, unless it is worked at a low duty.

There is another factor which has a great deal to do with the success of water tube boilers; that is, the size of furnace and length of the fire bars. If they are to compete with the Scotch boiler, they must have the furnace to conform more nearly to its conditions.

In the Scotch boiler the furnace rarely exceeds 21 square feet of grate surface and $5\frac{1}{2}$ to 6 feet length of fire bars, yet water tube boilers are built with sixty or more square feet of grate surface in one furnace, and the fire bars 7 to 9 feet in length. With such fires to manipulate, how can one expect to get the efficiency out of the water tube boiler that he does out of the Scotch boiler?

The statement is often made that water tube boilers contain a

very small quantity of water. This is more of an advantage than disadvantage, for this reason: steam can be raised to 100 pounds pressure from cold water in five to twenty minutes without injury, whereas in the Scotch boiler it takes from three to six hours. This means a saving of so much coal and time, which in daily service would be from ten to twenty per cent. for the coal, to say nothing of the time saved.

The small quantity of water means a saving in weight and an increase of safety. The only advantage that a large quantity of water has, if it can be called an advantage, is that it does not require so close attention to the feed. In the water-tube boiler the same end is attained by the use of an automatic feed water regulator.

TRIALS OF THE NICLAUSSE SAFETY WATER TUBE BOILER.

By Jay M. Whitham, Esq., Member.

Description.—The Niclausse Boiler consists of a steam and water drum, to which are connected vertical malleable iron headers. To the headers are secured "Field tubes," set at an angle of six degrees to the horizontal. The headers are arranged as shown in Figs. 1 and 2, and are divided into compartments, as shown in Fig. 3. The outer tubes are screwed into tapered malleable iron sleeves, which also contain the sleeves holding the circulating tubes. The main sleeve fits tapered sockets in the faces of the header, and is held in place by a dog and stud bolt. One bolt holds two sleeves.

The water circulation is as follows: The feed water enters a tray in the front of the steam drum, where it is heated to the temperature of the steam and impurities are precipitated. It then overflows into the drum, descends the front compartments of the headers, passes in solid streams down the inner circulating tubes to the extreme end of the "Field tubes," where it turns and passes upwards to the front through the annular space between the tubes. The mixed water and steam then passes upward through the inner compartments of the headers and discharges into the drum.

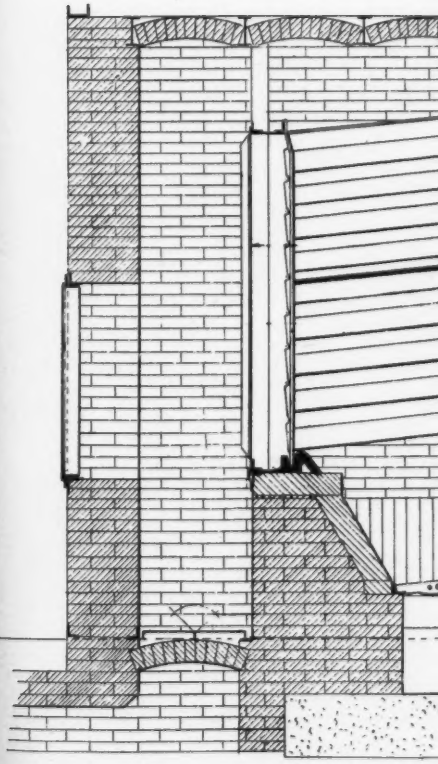
The impurities in the water are removed through surface and bottom blows.

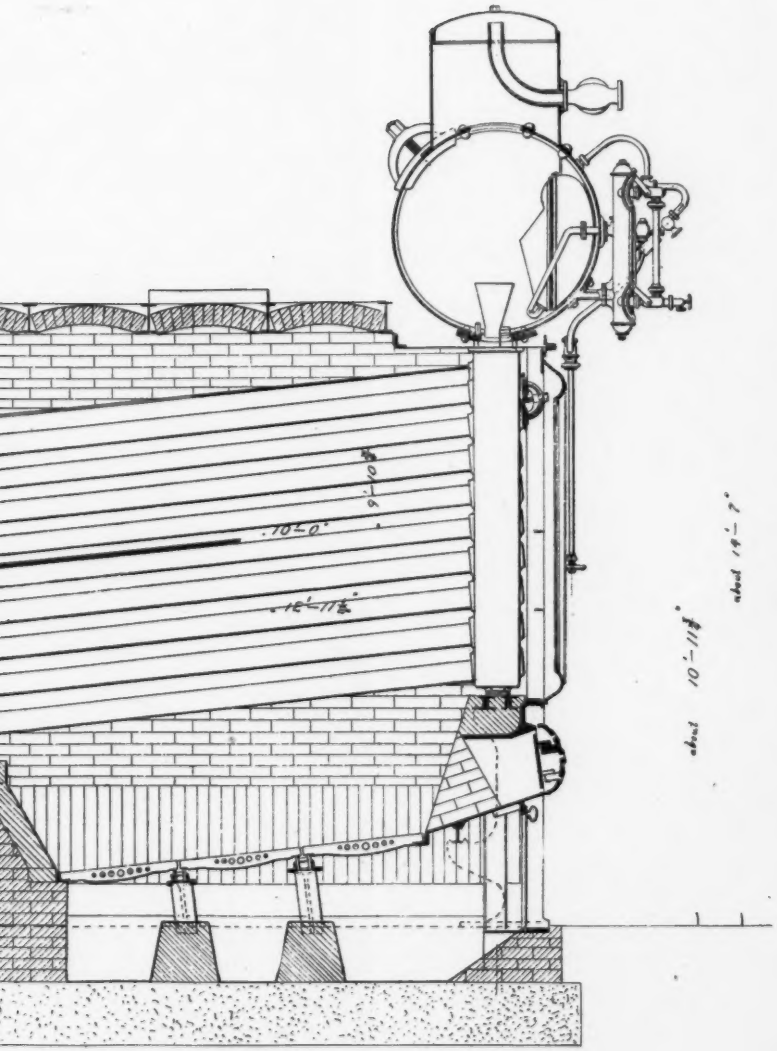
The gases circulate in an "S" shaped path among the tubes, the amount of baffling given being regulated by the conditions of draft in the particular setting.

For stationary uses the boiler has brick sides and bridge walls. As a marine boiler it has wrought iron sides or jackets lined with a refractory material.

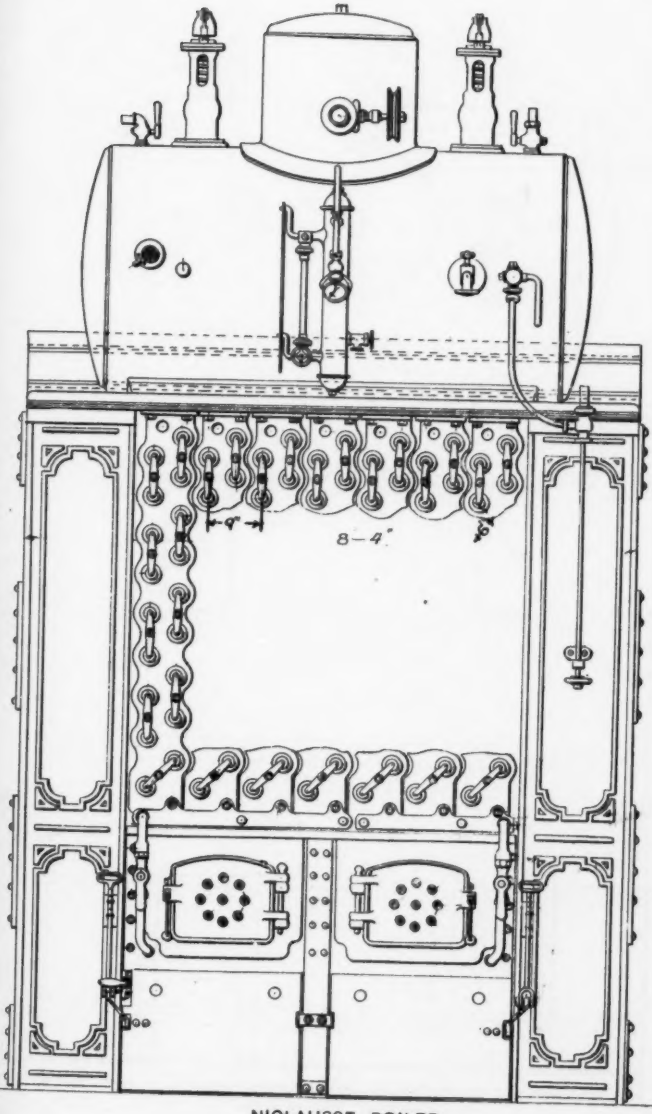
The ease with which tubes may be withdrawn is shown in Fig. 2. In a recent trial, the time required for hauling fires, emp-

GÉNÉRATEUR PERFECTIONNÉ, Brevet NICLAUSSE





NICLAUSSE BOILER.



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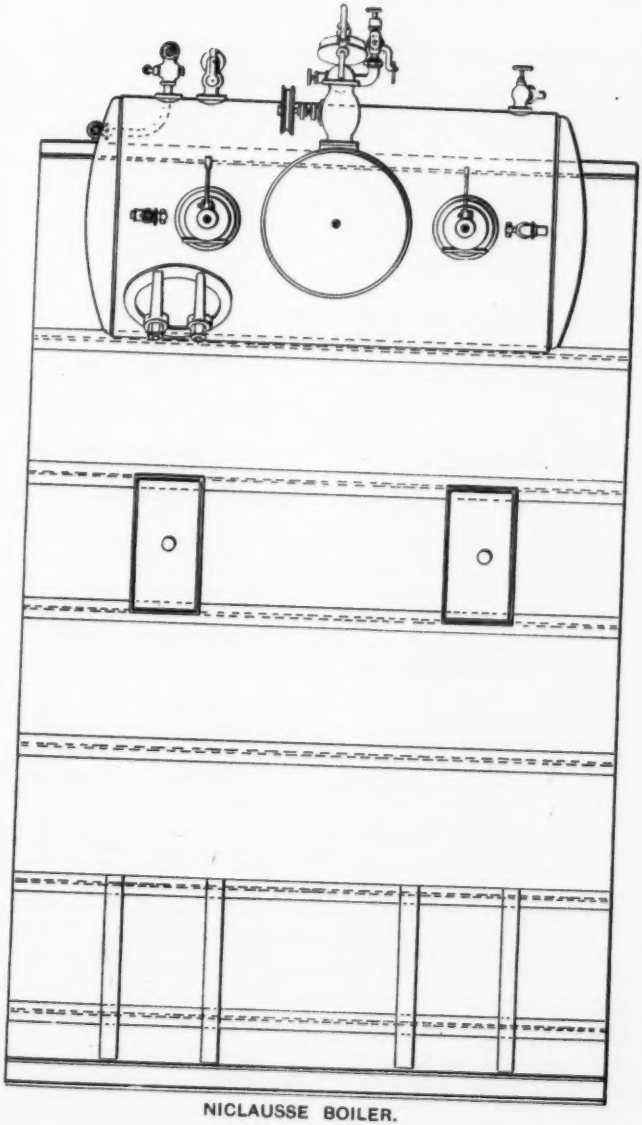


NICLAUSSE BOILER.

tying the boiler, removing and replacing a tube, filling the boiler, building a fire and getting up full steam pressure, was only 76 minutes, while but 6 minutes of this time was actually used in removing and replacing a set of tubes. The tubes being so readily and easily removed, it follows that they may be taken out when necessary, and thoroughly and quickly cleaned by a few raps of a hammer. There is no cutting out of the tubes, since none are expanded, and because all joints are ground to a metallic fit.

Dimensions of Boiler Tested.—The boiler tested at the dry dock of the Wm. Cramp & Sons' Ship and Engine Building Company, in Philadelphia, was of the stationary form and setting, and had the following dimensions:

126 tubes, 9 high × 14 wide, $3\frac{15}{16}$ inches diameter × 8 feet 4 inches effective length.
126 circulating tubes, 2 inches diameter, made of No. 20 sheet iron, painted.
Setting, 8 feet 4 inches wide × 10 feet long × 14 feet 7 inches high.

Floor space, square feet	83.3
Volume occupied, cubic feet	1,215

Drum, 36 inches × 72 inches, containing 18 square feet of liberating surface and 27.5 cubic feet of steam storage.

Water volume, cubic feet	106
Weight of boiler and fittings empty, pounds	26,270
Weight of boiler in service, exclusive of brickwork, pounds	32,100
Heating surface in tubes, square feet	1,081.5
Heating surface in headers, square feet	10.5
Heating surface, total square feet	1,092.0
Grate surface, 5 feet 5 inches wide × 5 feet 2 inches long, square feet	28

Fifty per cent. air openings.
Ratio of heating to grate area, 38 to 1.
Baffles, 55 inches long; throats, 45 inches long × 28 inches effective width.
Stack, 48 inches diameter × 60 feet high.

Manner of Testing Boilers.—The trials were conducted in accordance with the code of rules advised by the American Society of Mechanical Engineers. The coal, ash and water were weighed. Large samples of coal were dried at a temperature of 200 degrees Fahrenheit, to determine the moisture. Samples of coal collected on the trials were analyzed by Mr. Jesse Jones, analytical chemist, Philadelphia. The flue gases leaving the

boiler were analyzed at short intervals during the progress of the trials.

The pressure of steam, temperature of the feed water, temperature of the gases in the stack and readings of the wire drawing calorimeter were taken at 15-minute intervals. The calorimeter was calibrated on each test. The drafts in the furnace, between the baffles, at the top of the back flue, and in the stack were read every 30 minutes.

The firing was done by the regular stoker at the dry dock, who had other duties to perform at the same time.

On bituminous coal trials, standing or bare grate starts and stops were made, the wood used for starting the fires being considered as possessing 40 per cent. of the calorific value of an equal weight of coal. On trials with anthracite buckwheat coal, the tests were started and ended with a two and one-half-inch covering of clean, incandescent coals on the grate.

All instruments used were standardized. Coal records were kept in triplicate and water records in duplicate.

Object of Tests.—The trials were made to determine—

1. The capacity and economy of the boiler.
2. The uses and lósses of heat contained in the fuel burned.
3. The responsiveness of the boiler to sudden and fluctuating steam requirements.
4. Whether or not the water surface remains normal as the firing is forced.
5. The adaptability of the boiler for burning inferior grades of anthracite as well as bituminous coals.

Coals Used on Trials.—The anthracite coal used was of buckwheat size from the Lykens Valley (Penna.) region. It was of such size as is obtained in screening through a $\frac{5}{16}$-inch square, and riding over a $\frac{3}{16}$-inch round punched plate. It was clean and of fair quality. Proximate analyses were

Moisture,	2.2
Volatile gases,	10.0
Fixed carbon,	76.6
Ash (red),	11.2
Total,	100.0

The complete analysis of the buckwheat coal was

Carbon,	81.95
Hydrogen,	8.50
Oxygen and nitrogen,	3.75
Volatile sulphur,	0.62
Ash,	11.20
Total,	100.02
Sulphur in ash,	0.14
Total sulphur,	0.76

Thermal value of dry fuel was 13,137 B. T. U. per pound.

The run of mine, semi-bituminous coal used was known as the Eureka, mined in the Clearfield (Penna.) district, and gave proximate analyses as follows:

Trial No.	482	484
Moisture	1.55	0.80
Volatile gases	23.00	23.60
Fixed carbon	70.05	71.10
Ash	5.40	4.50
Total	100.00	100.00

The complete analyses were:

Carbon	82.40	83.18
Hydrogen	3.16	3.99
Oxygen and nitrogen	8.46	7.75
Volatile sulphur	0.58	0.58
Ash	5.40	4.50
Total	100.00	100.00
Sulphur in ash	0.14	0.13
Total sulphur	0.72	0.71
Thermal value of 1 pound dry coal, B.T.U.	13,562	13,936

Nature of the Combustion.—The nature of the combustion, with bituminous coals, was determined by volumetric analyses of the flue gases, made with an Orsat apparatus. The average results, together with deduced results, are as follows:

FLUE GAS ANALYSES WHEN BURNING BITUMINOUS COAL.

Trial No.	482	484
Number of samples analyzed	9	10
Carbonic acid	8.2	10.1
Free oxygen	10.0	8.8
Carbonic oxide	0.8	0.75
Nitrogen	81.0	80 35
Dry coal burned per hour per square foot of grate, pounds	12.8	21.9
Air required for complete combustion per lb. of coal, pounds	10.60	11.06
Air supplied for combustion, pounds	19.7	18.7
Excess air supplied, per cent	86.0	69 0
Kind of draft	Natural.	Natural.

These analyses show:—

1. An excellent distribution of the air passing through the bed of fuel.

2. A less excess of air than is usually supplied for combustion with natural draft, and a consequent saving in the heat lost in the stack gases.

3. Nearly perfect combustion, as the unburnt gas (carbonic oxide) was less than one per cent. of the volume of gases passing from the boiler.

Results of the Trials.—The results of the trials, given on the following page, show:—

1. That the fuels required but a slight furnace or combustion draft to burn at the rates noted.

2. That the resistance of the gases of combustion in traversing the various passes among the tubes was slight.

3. That the moisture in the steam was slight, even when the boiler was forced, and that the steam was commercially dry.

4. That the percentage of the total heat in the coal that was actually utilized in making dry steam was within from 2 to 3 per cent. of the highest authentic and "believable" results on record.

5. It follows that the economic evaporation was high.

6. The boiler on test 484 developed a commercial, or boiler H.P. on 5.5 square feet of heating surface, showing, at the same time, an efficiency of 77.5 per cent.

TRIALS OF NICLAUSSE BOILER AT WORKS OF CRAMP & SONS.

No. of Trial	479	481	482	484
Number of boilers tested	1	1	1	1
Duration of trial, hours	10	10	10	10
Total water heating surface per boiler, square feet	1,092	1,092	1,092	1,092
Width of grate, feet	5.42	5.42	5.42	5.52
Length of grate, feet	5.17	5.17	5.17	5.17
Area of grate per boiler, square feet	28	28	28	28
Ratio of water heating to grate surface	39 to 1	39 to 1	39 to 1	39 to 1
Kind of grate	Common stationary.	Common stationary.	Common stationary.	Common stationary.
Air space in grate, per cent	50	50	50	50
Height of stack above dead-plate, feet	60	60	60	60
Area of stack (48 inches diameter), square feet	12.56	12.56	12 56	12.56
Ratio of stack area to grate surface	1 to 2.23	1 to 2.23	1 to 2.23	1 to 2,23
Atmospheric pressure per barometer, pounds	14.70	14.80	15.11	14.92
Steam pressure in boiler by gauge, pounds	48.4	48	48.5	54
Draft in flue behind boiler, inches	0.22	0.23	0.16	0.34
Draft in furnace, inches	0.14	0.11	0.10	0.16
Average temperature of external air, degrees Fahrenheit	38	30	25	35
Average temperature of fire room, degrees Fahrenheit	80	78	78	80
Average temperature of feed water entering boiler, degrees Fahrenheit	37	36.8	35.3	35.8
Average temperature of escaping gases, degrees Fahrenheit	504	530	546	645
Kind of coal	Lykens Valley anthracite, Buckwheat.		Clearfield bituminous.	
Total amount of coal consumed, pounds	3,887	3,850	3,670	6,316
Moisture in coal, per cent	1	1	2	3
Dry coal consumed, pounds	3,848	3,811	3,597	6,127
Total refuse in coal, pounds	521	390	213	304
Percentage of refuse in coal	12.2	10.2	5.95	4.96
Total combustible (dry weight of coal, less refuse), pounds	3,328	3,421	3,384	5,823
Quality of steam, dry steam being taken as unity	0.997	1.00	0.995	0.990
Water pumped to boiler and apparently evaporated, pounds	33,287	33,756	30,446	57,080
Water actually evaporated, corrected for quality of steam, pounds	33,187	33,756	30,294	56,509
Equiv. water evap. into dry steam from and at 212° Fahrenheit, pounds	40,123	40,777	36,656	68,492
Equiv. water evap into dry steam from and at 212° Fahr. per hour, pounds.	4,012	4,078	3,666	6,849
Total heat derived from fuel per pound of dry coal, B.T.U	10,075	10,336	9,844	10,800
British thermal units by analysis per pound of dry coal, B.T.U	13,137	13,137	13,562	13,936
Combined efficiency of furnace and boiler, per cent	76.5	78.7	74.3	77.5
Water evap. per pound of dry coal from and at 212° Fahrenheit, pounds	10.43	10.70	10.19	11.18
Water evap. per pound of combustible from and at 212° Fahrenheit, pounds.	11.88	11.92	10.83	11.76
Water evaporated from and at 212° Fahrenheit per hour per square foot of heating surface, pounds	3.68	3.73	3.36	6.27
Dry coal burned per square foot grate surface per hour, pounds	13.7	13.6	12.8	21.9
Pounds of dry coal per hour per horse power developed	3.31	3.23	3.39	3.09
Horse power on basis of 34.5 pounds per hr. evap. from and at 212° F	116.3	118	106.2	198.5
Horse power, builders' rating	100	100	100	100
Horse power developed above or below rating, per cent	16.3	18	6.2	98.5
Heating surface per horse power developed, square feet	9.39	9.26	10.28	5.5
Date of trial, 1896	December 21.	December 23.	December 28.	December 30.

Uses and Losses of Heat.—From the data already given it is seen that the uses and losses of heat were as follows:

Trial	482	484
Boiler efficiency, per cent	74.3	77.5
Heat lost by the hot gases in the stack, per cent	16.9	16.9
Heat lost by imperfect combustion, per cent	4.2	3.6
Heat lost in the ash and by radiation, per cent	4.6	2.0

Trials by Profs. Kennedy and Unwin.—The foregoing trials are practically identical with the tests of a smaller sized Niclausse boiler, made at Thames-Dutton, England, in 1894, with "Powell-Duffryn" coal, by Profs. Kennedy and Unwin (see "London Engineering," July 19th, 1895).

The general results of the trials were:

RESULTS OF TRIALS BY PROFS. KENNEDY AND UNWIN.

Trials	1	2	3
Pounds of coal burned an hour per sq. ft. of grate	13.5	13.3	25.6
Draft in stack, inches	0.2	0.2	0.75
Temperature of gases, degrees F	512	503	732
Ash in coal, by trial, per cent	4.4	4.4	.....
Moisture in steam, per cent	1.1	1.0	.....
Thermal value of pound of coal, B.T.U.	13,860	13,860	.....
Efficiency of boiler and furnace, per cent	72.9	73.11	.....
Pounds of water evaporated at and from 212 degrees F., per pound of coal	10.47	10.50	10.42
Pounds of water evaporated at and from 212 degrees F., per pound of combustible	10.95	10.98	.....
Pounds of water evaporated per hour at and from 212 degrees F., per sq. ft. of heating surface	3.39	3.33	6.34
Square feet of heating surface to one commercial, or boiler H.P. developed	10.24	10.40	5 42

The uses and losses of heat on these trials were:—

Trials	1	2
Boiler efficiency, per cent	72.90	73.11
Hot gases, loss in per cent	16.79	17.56
Heat lost in imperfect combustion, per cent	3.61	1.33
Heat lost in the ash, per cent	0.96	0.98
Heat lost by radiation, per cent	5.70	7.02
Pounds of air supplied for combustion per pound of coal	20.8	22.3

THE NICLAUSSE AS A STATIONARY BOILER.

The Niclausse is compared with other well known types of stationary boilers in the following table:

Name of boiler.	No. in battery.	Heating surface to I.H.P.	Ratio H.S. to G.S.	Per square foot of water heating surface.						
				Shipping weight.	Red brick.	Fire brick.	Floor space.	Volume occupied.	Steam storage.	Liberating surface.
		Sq. ft.		*Lbs.*	*No.*	*No.*	*Sq. in.*	*Cu. ft.*	*Cu. in.*	*Sq. in.*
Babcock & Wilcox.....	2	11.5	46.4	21 8	5.7	1.1	13.4	1.35	102	7.2
National.....	2	11.0	35 0	19.3	5.4	1.3	15.2	1.39	82	5.8
Heine.....	2	7.5	43.8	19.4	7.0	1.6	15.2	1.43	81	6.9
Wood	2	11.0	45.9	14.7	8.4	1.1	14.1	1.77	105	5.5
Stirling.....	2	11.5	44.2	12.2	5.6	1.0	10.0	1.29	79	3.8
Galloway.....	2	4.6	29.2	49.1	25.2	0.0	45.7	3 25	341	22.9
Horizontal Tubular....	4	12.0	35.8	14.6	12.8	0.9	16.6	1.36	110	8.2
Berry	2	6.9	36.3	12.2	2.8	0.3	9.2	1.28	100	3.9
Climax.....	1	6.5	39 5	25.7	2.4	0.5	7.1	1.63	56	0.7
Corliss	2	10.8	42.0	22.2	0.0	0.6	6.5	1.36	97	1.5
Niclausse.....	5	10.9	33.6	24.1	4.0	0.5	9.5	0.96	33	2.3

A study of this table shows:

1. That in the comparison the Niclausse Boiler is placed at a disadvantage because five boilers are taken as forming a battery of 500 H.P., while in practice from two to three boilers of a larger size would be used.

2. Its shipping weight is about the average of that of the boilers given in the table.

3. It requires less red and fire brick in its setting than do other forms of horizontal boilers.

4. It takes up less floor space than any other horizontal boiler.

5. It occupies less volume than any boiler given in the table.

6. It has small steam storage and liberating surface, but all the trials heretofore given prove that the steam is commercially dry.

THE NICLAUSSE AS A MARINE BOILER.

The Niclausse is extensively used as a marine boiler, and while showing as good, and often better economic evaporations than the Scotch marine type, possesses many additional advantages for use afloat, as is seen from the following table, in which they are compared for like conditions of running and pressure:

Type of marine boiler	Scotch.	Niclausse.
	Per square foot heating surface.	
Weight of boiler empty, pounds	41.6	25.7
Weight of water in boiler, pounds	23.2	5.3
Total weight in service, pounds	64.8	31.0
Floor space, square inches	12.5	7.9
Volume or space occupied, cubic feet	1.12	0.8
Steam space, cubic inches	303.6	33.2
Liberating surface, square inches	11.2	2.3

Features of the Niclausse Boiler.—The advantages of this boiler may be summarized as follows:

1. *Safety.*—The strength of the boiler is limited by the strength of the tubes. The headers and drum may always be made the strongest parts of the boiler. The steam drum is not exposed to the flame or gases. The strain on the stud bolts holding the tubes in place is practically *nil.*

The boiler has absolute freedom for expansion.

2. *Simplicity and Accessibility.*—The boiler is simple in design. Every part is accessible for examination, cleaning or repair without entering the setting.

3. *Maintenance.*—The boiler may be repaired without employing any extra labor. One man can replace a tube in five or six minutes. The boiler never requires patching, since the drum is not exposed to the flames. If the tubes become scaled they can be thoroughly and completely cleaned by a few raps of a hammer on the outside of each tube. The tubes are removed in cleaning. There are no hand-hole plates requiring gaskets. The tubes are held in sleeves, resting in sockets, having ground and metallic joints. An ordinary fireman can re-grind these joints when needed.

4. *Circulation.*—The boiler has a positive and rapid circulation in a defined path. The water is compelled to fill the entire length of every tube. The resistances to the circulation of the water are so slight that the water level in the drum is steady and normal, even when the boiler is evaporating eight pounds of water to the square foot of heating surface, or developing a commercial or boiler horse-power on 4.3 square feet of heating surface.

5. *Responsiveness.*—The boiler responds quickly to any sudden or unusual demand for steam.

6. *Dry Steam.*—The trials show that the steam has only one per cent. of moisture when the capacity of the boiler was doubled. When it is remembered that from six to seven per cent. of moisture in the steam is necessary to open the relief valve of an engine, it is evident that the Niclausse boiler has ample steam storage and liberating surface and makes commercially dry steam.

7. *Economy.*—The tests show that the economy of the Niclausse boiler is within from two to three per cent. of the best authentic and "believable" record, made under the most favorable and expert conditions.

8. Small floor space required.

9. Small volume occupied.

10. Small weight of parts.

11. The boiler may be made narrow and high, or wide and low, or long or short, to suit the varying requirements of vessels, office buildings, &c.

12. The boiler may be carried in small parts on pack mules over mountains, or it may be taken through small doors and openings in piecemeal.

DISCUSSION.

P. A. Engineer W. M. McFarland, U. S. N.—The two papers we have just heard are very interesting, and, inasmuch as I have contributed a little to current engineering literature on this subject, a few remarks may be in order. I have already expressed the opinion that the water-tube boiler has come to stay, and my belief is that, in time, it will entirely displace the cylindrical boiler on board ship. Before it can do so, however, one point must be looked after by the manufacturers of water-tube boilers, namely: the economy at fairly high rates of combustion. While there are a number of water-tube boilers which do give good results at high rates of combustion, there are others in which the uptake temperature is altogether too high. A recent case of two of our vessels, the *Wheeling* and the *Marietta*

illustrates this point. The *Wheeling* has cylindrical boilers, with the Howden system of forced draft while the *Marietta* has Babcock and Wilcox water-tube boilers. On their trial trips they developed about the same horse power; and, as the engines are absolutely identical, if the boilers had been of the same economy, the cost of a horse power should have been the same. On the contrary, with the water-tube boiler, a horse power cost nearly half a pound of coal more than with the cylindrical boiler fitted with Howden draft. The uptake temperatures were taken in the two cases, and, with the cylindrical boilers, the temperature was about 550 degrees, while with the Babcock and Wilcox boilers, from 850 to 1,100 degrees, a difference of from 300 to 550 degrees, which easily accounts for the difference in economy.

As I have said elsewhere, I don't look on this as a difficulty in the principle of the water tube boiler, but merely as a point in design which can be remedied if care is taken; but I feel that water tube boiler makers are standing in the way of the rapid introduction of the type so long as they do not take care to prevent these high uptake temperatures with consequent loss of fuel.

Mr. John Platt, Associate.—I am sure we have listened with a great deal of interest to the two papers on water-tube boilers, and should be able to gather some good points from them. I can agree, in the main, with the points made in Mr. Almy's paper, but would take a very decided exception to the statement that a good boiler should be so designed that the tubes are arranged in nests, so that any particular nest of tubes can be, at least on paper, taken out readily and another nest substituted. An immense amount of ingenuity has been wasted by water-tube boiler men in the last few years, in trying to get up a design in which tubes can be inserted in nests. This generally means resorting to screwed ends and manifolds, which are undesirable for high pressures.

The proper thing to do is to build a water-tube boiler, using thoroughly good boiler making details; expanding the tubes; making them of good material, and thick enough to stand wear; and so arrange the whole boiler that its life as a whole will be a long one, and repairs reduced to a minimum.

Too many marine water-tube boilers are designed with steam engine details instead of those of a boiler maker; steam drum heads are bolted up like a cylinder cover, and in some cases drums are made in halves with very large flat joints as in a valve chest. This is not boiler making, and should not be tolerated.

In the water-tube boilers of some of our ships too little attention is paid to the temperature of the casing. This is a very important question and means a great deal to the fire room force. It is well known that a water-tube boiler can be so designed that the gases at the outside of the boiler do not come in contact with the casing, but simply with a wall of tubes, and thus only the tube temperature is carried to the outside casing. In some boilers, where the whole of the casing is practically an uptake, the temperature of the fire room is often unbearable. Several members have spoken of the very high flue temperature found in many water tube boilers, particularly when they are forced. This is not at all a necessity in a water-tube boiler, but a result of the design of the boiler in which it is taking place. A water-tube boiler, to be good for marine work, should be capable of being forced to the very utmost and still be economical. With such a boiler, under ordinary conditions of working, the efficiency will be very high, indeed.

Mr. Charles Ward.—Mr. McFarland has just stated that the department has recently built two gun boats (*Wheeling* and *Marietta*) in every way similar except that the former is fitted with Scotch and the latter with water-tube boilers, and that on the recent trial trips the temperature in the uptakes was very much higher in the water-tube than the Scotch boilers. We are aware that this is an objection frequently urged; but let us look at the facts in this particular case. In the *Wheeling*, fitted with Scotch boilers, we not only have the Scotch boilers, but have in addition a device known as Howden's forced draft. The arrangement, as you all know, is a large box, which takes the place of the ordinary breeching, fitted with numerous tubes. The gases of combustion pass through this box in contact with the tubes on their way to the uptake. The air furnished by the blowers to the fires

passes through the tubes for the express purpose of recovering the waste heat from the gasses from the Scotch boilers before they enter the uptakes, in much the same manner and for the same purpose as feed water heaters are fitted. It is obvious if the temperature of the gases were not high there would be little gained from the use of Howden forced draft. Its very presence implies a large waste in the uptakes of the boilers to which it is attached.

I have no doubt, if Mr. Howden were present, he would tell with much satisfaction how great the temperature of the gases is on entering his appliance and how much he recovers, which would be lost but for the intervention of his economizer.

This being the case, it is easy to see that the comparison is not a fair one and that the low temperature in this case, at least, is not any advantage the Scotch boiler has over its new competitor, but is due to secondary means.

High temperature in the uptake is a bugbear wherever present, and ought to be deprecated. It often exists when there is no necessity, as the result of improper firing. Long use of the Scotch boiler has made attendents familiar with methods which in care-taking and firing produce the best results, and the best effort of the ablest engineering talent of the world has been many years in bringing the Scotch boiler up to whatever usefulness and efficiency it possesses to-day. When the water-tube boiler has passed through the same process of evolution we shall have something immeasurably better. The methods which applied to the old do not apply to the new, and our engineers and operators must cast off prejudices and study the best methods of care and treatment, necessary to the new conditions. When the engineering fraternity has had as much experience with water tube boilers as with the old type the result will be eminently satisfactory.

High stack temperature is usually an evidence of improper firing. A well designed water-tube boiler has usually a large fire box or combustion chamber. Sometimes this is lined with firebrick. If the fire is too thick or too heavy, perfect combustion cannot take place; what should be a combustion chamber becomes a gas retort, and dry distillation takes places. The gases resulting fill the passages through the boiler and the uptake; presently a

clear place breaks through the fire, and sufficient heat and air as a result ignites the whole; the gases still evolving from the heavy fire continue to burn in the upper parts instead of in the combustion chamber. The *fires should be of such thickness and fed at such intervals as would secure the gases being generated and consumed* in the same ratio. When this is done the highest economy, efficiency and cool uptakes result. What we need is a corps of trained firemen who would second the efforts of the engineer, as a trained nurse does the doctor. An indifferent one can neutralize the economy of the finest expansion engine. While the ship is running the fireman disposes of *more value* than perhaps any other man aboard, and the saving resulting from good, intelligent firing as compared with the worst is anywhere from 15 to 30 per cent.

P. A. Engineer Emil Theiss, U. S. N.—In the design of water tube boilers, many of the difficulties that were at first experienced have been overcome. This may be said especially of the subject of the water circulation, and many boilers are now built and sold that are satisfactory in this respect.

There remains, however, another problem which has not yet met a full and satisfactory solution. I refer to the proper circulation of the products of combustion, and the consequent reduction of the temperature of escape gases, to what we are accustomed to regard as a normal one, with attendant increase in economy of fuel consumption. I have been present at trials of boilers of the tubulous type on board ship, when the temperatures in the uptakes and smokepipes, though unrecorded, were such that even a reasonable economy was out of the question, and the interior of uptakes and lower portion of smokepipe, including armor bars, &c., were in a state of collapse at their conclusion.

Forced draft is now a *sine qua non* in naval machinery design, and a boiler to answer the requirements of modern naval practice must be capable of being forced without suffering material injury and without consuming an excessive amount of fuel. Hitherto tubulous boilers have been tried almost exclusively on the closed fire room system of forced draft. In one of the recent ships of

our Navy, the gunboat *Nashville*, on which Scotch and tubulous boilers of the *Yarrow* type are used in conjunction, the closed ash-pit system was introduced and successfully tried. One of the difficulties to be met with and overcome in the use of this and other similiar systems of forced draft is the question of the tightness of the boiler casing to prevent excessive leakage of air into the fire room, accompanied with fine dust and cinders. Further experience on this point is necessary. The Howden and similar systems of forced draft have been tried with great success with Scotch boilers, resulting in increased economy and in great reduction of weight. It seems reasonable to suppose that these same systems should give equally good account of themselves when used in conjunction with boilers of the tubulous type. In this way, also, would be found a solution, or a partial solution, of the question of high uptake temperatures, above alluded to as constituting one of the problems of tubulous boiler construction yet awaiting a satisfactory solution. That this problem of the proper circulation of the gases of combustion can, however, be solved by design, is exemplified by the boilers of torpedo boats Nos. 3, 4 and 5, the *Foote*, *Rodgers* and *Winslow*. These boilers were tried under air pressures of 4 inches and over, yet the temperature of the escape gases remained such that the hand could at all times be borne on the bottom of the smokepipe casing.

The same object of reducing the temperature of the uptake gases by abstraction of heat in the uptakes may be and is sometimes reached by fitting feed water heaters in the uptakes, as is the practice of the Babcock & Wilcox Boiler Company in their marine designs. This method of feed water heating is of long standing, has been often condemned, and will most certainly have to be superseded by other more practical and efficient means of accomplishing the desired end.

Mr. Jarvis B. Edson, Member.—I have heard with much interest the papers on water tube boilers, because reliable data regarding the various types of them cannot be found. I am sure engineers and yacht owners are quite in the dark regarding the

matter even after many costly and annoying experiences with boilers from the leading makers.

We are accumulating for pleasure purposes a large fleet of steam yachts, many of which in time of war could greatly aid the Government, so that, aside from other considerations, it is desirable to have them of the best equipment and construction money can secure, and it is for this reason I speak of the boiler element from the standpoint of a yachtsman.

At best a steam yacht is a costly toy, but when there are added the elements of unreliability and danger the matter becomes serious, and the light weight, quick steaming pipe boiler for such purposes appears to be still in the experimental stage, and we are without full and reliable data covering those things which make a boiler. One 100-horse launch boiler I owned would change its water level frequently from ten to twelve inches on the least variation of conditions. Another I saw blow out had a "trap" in the pipe leading from lower end of glass water gauge to water space, so that it always indicated one-half inch water in the glass. This defect in connecting up could not readily have been detected by the new engineer unless his previous experience had made him mindful of such a possibility. In this case the pressure of 220 pounds was sufficient to blow the fire a considerable distance, setting fire to the boat and badly scalding the engineer and fireman.

Another I know of set the boat on fire when a few important brick became dislodged, whereas such a contingency could readily have been guarded against by the makers by changing the design or properly insulating for such a possibility. In another boiler I owned there were 1-inch horizontal pipes exposed to the hottest part of the fire, which, when crowded, would form steam more rapidly than it could escape in one direction, owing to the distance and number of bends it had to traverse in order to reach the steam drum. The consequence was that when forced to a certain point the steam would suddenly go in both directions, holding the water back (or, in other words, the circulation ceased), the pipes became hot, and steam was made faster than it was possible to get rid of it through an open throt-

tle and safety valve raising, and prompt killing of the fire had to be resorted to. And so I might contiuue and enumerate cases to prove my point, that, as now made by the leading manufacturers and as installed by the best of them, the pipe boilers are not what they are capable of being made, and the subject of their proper design and construction is of too much importance to the Naval engineer to remain longer unknown.

There are also many valuable features in boilers of small size when made from pipes of small diameter properly arrranged, that I feel the subject of their proper design, construction and installation and all data as to efficiency, operation and care should be taken up and worked out by a board of Naval engineers for the benefit of both the Naval and merchant service.

Col. E. D. Meier, Associate.—There is one point in Mr. Almy's paper that I take decided exception to, and that is where he states as his belief that the limit for tubes should be 2 inches in diameter by 12 feet long. I have had a boiler in use for many years with tubes $3\frac{1}{2}$ inches in diameter and 16 feet long, and where the consumption per grate has been as high as 52 pounds per square foot per hour.

Mr. Charles Ward, Associate.—(Remarks submitted after the meeting.)—I wanted to reply to Mr. Edson's remarks at the meeting, but was anxious to have an accurate account of what he said, and so have waited until his revised remarks were received.

I feel he has been most unfortunate in his experience and in his selection of boilers, and I think he presents only one side of the case, not by any means general. I am also a yacht owner of some ten years' experience, and a designer and builder of several styles of water-tube boilers of twenty years' standing, so that my views may have some weight. If we take the reports of boiler explosions published in the "Locomotive," by the Hartford Boiler Insurance Co., we are appalled at their extent, but if we also consider the great number of boilers in use, and the very important part they play in the work and comfort of

life, we begin to feel that a steam boiler is a very safe and subservient servant, and that Mr. Edson has stated a very small side of the case. No new appliance reaches success without casualties and difficulties, and to this the water-tube boiler is no exception. On the other side I may quote a few of a great many cases where boilers of this type have proved most efficient. I have had a yacht with a water-tube boiler for eight years, always ready to go on fifteen minutes' call; in that time it never gave a moment's trouble or cost a cent. I sold her two years ago, and she is still doing well. Her successor, my present boat, is equally satisfactory.

The War Department steamer *Hamilton*, in New York harbor, has a Ward boiler now thirteen years old, in constant use with trifling cost for repairs. The U. S. A. Engineer Corps has two boats, one having 250-H.P., water-tube boilers, which ran fourteen years on about $100 for repairs, the other is in her fifth year without repair and no trouble. The U. S. Revenue Cutter *Hudson*, on duty in New York waters, has a 500-H.P. Ward boiler, now in its fifth year, which has not cost a cent for repairs or a moment's anxiety. The U. S. Navy has used some two hundred water-tube boilers on their launches during the past thirteen years, the first being furnished for the *Black Jack*, in 1885. The Department is still putting them in, which is sufficient evidence that they are the most satisfactory, all things considered.

Many of the finest yachts in New York waters have water-tube boilers of our own and other makes, which have given most excellent results. The *Golden Gate*, owned by Commodore Archibald Watt, has a 500-H.P. Ward boiler doing good service and in use since 1889, it being the third boiler of same make in this boat. As a matter of fact such yachts as we have to-day would not be possible but for water-tube boilers. They have made speed in yachting possible which could not be obtained with the old conditions, especially for small boats.

We may very properly ask where would our torpedo boats of 30 knots and upwards be without water-tube boilers, and this reminds me that the *Cushing's* water-tube boilers have given ex-

cellent service, the first set of tubes lasting some six or seven years.

The more we view the matter, the more apparent it seems that our friend's lines have fallen in unpleasant places, and that his experience can hardly have been with "the leading manufacturers," for the condition he describes and the former are not synonymous.

In regard to the remark that "reliable data regarding various types of water-tube boilers cannot be found," I am pleased to say that Mr. Isherwood made very exhaustive tests and a report in 1884 of a Ward launch boiler, thousands of which we circulated. He also made most complete tests and reports of the Herreshoff boilers on the yachts *Siesta*, *Leila*, *Javlin*, *Kelpie*, and upon the French vedette boats, all which are marvels of accuracy and detail, and which contain most useful data hard to find elsewhere. A U. S. Navy experimental board made investigations and full report of Mr. Perkins' boiler on the *Anthracite*. A most important U. S. Navy board made most exhaustive tests and report of the fullest character on the Ward, Cowles, Thornycroft and Babcock & Wilcox water-tube boilers, and some one made reports on the Belleville. Professor Denton has made reports on the Mosher, Professor Kennedy on the Thornycroft, and more recently Professor Barnes on the Almy, and now Mr. Whitham on the Niclausse. The results of these several tests, except the last two, were all thrashed out in the discussion on Engineer Leonard's paper in the Society's journal, and several papers have been read at the various societies at different times by Engineers McFarland and Griffin and myself on this side, and by Col. Soliani, Mr. Thornycroft, Mr. Yarrow, Mr. Milton, Mr. Seaton and, I think, Mr. Normand. Most of these will also be found in the Society's journal. The best engineering talent of the world is studying this question, and no doubt better things are to come.

BOILER TESTING WITH VARIOUS FUELS.

By Col. David P. Jones, M. E., Member.

Within the past few years the development of the steam boiler, especially of the water-tube type, has been most marked, and manufacturers and steam users, as well as engineers, have awakened to the necessity of proper and systematic testing in order to ascertain the commercial as well as the technical points involved. Indeed, the old-fashioned method of building and selling boilers upon a very broad rule-of-thumb basis as to their relative merits has become obsolete, for, at the present time, the sale of almost every boiler is accompanied by specific guarantees of its possible performance, and in the large number of cases it is also distinctly specified that the fulfillment of these guarantees is to be determined by trials or tests carried on under the supervision of reputable engineers of known skill and experience. So important has this testing or trial branch of the profession become, that many engineers confine much of their practice to this class of work.

Those engineers who do so limit their practice are constantly adding to the details of the records of boiler trials, new data and new methods, that tend not only to increase the value of such tests as regards the commercial points involved, but add much to the technical knowledge of fuel combustion, water evaporation, circulation of gases and water, transmission of heat, etc., until the somewhat broad practice of twenty years ago has given place to an almost laboratory minuteness of detail and exactness.

In a long and varied experience, not only in the care and management of boilers under steam, but in trials and tests of their capacity, economy and general merit, the writer has given the subject much attention, and it is proposed in this paper to give some of the results of his experience in such work, with sug-

gestions as to what may be the best methods to secure the best results.

In premising the remarks upon the subject, it seems almost unnecessary to state that in conducting tests under his supervision the practice has been to compel the boiler under test to give, legitimately, its best results. While this is properly the only standpoint for a reputable engineer to assume, the writer has known of many, very many, important tests having been conducted in a perfunctory sort of way, where the engineer in charge seemed to regard the taking and recording of data, and seeing that no improper methods were used to falsify the results, was about the sum and substance of the work to be done.

The substance of this paper will be devoted to the methods employed in using as fuel, coal, fuel-oil, waste gases of blast furnaces, and bagasse, or the residuum of milled sugar cane.

COAL AS FUEL.

In burning coal, the usual practice of the writer is to secure, previous to the test, whenever possible, a sample of the coal to be used, and make a proximate analysis of the same, in order to determine the amount of volatile matter and fixed carbon. The advantage of doing this is that it affords a clue to the most advantageous method of burning the coal in the furnace. As all engineers know, different coals require different treatment, and the action of the coal burning in the crucible is an index of what may be expected in the furnace.

In addition to making the proximate analysis, the heating value of the coal is also determined by burning in an oxygen calorimeter. This latter determination enables the conducting engineer to know, during the progress of the trial, whether the boiler is showing the per cent. of efficiency that ought reasonably be expected.

The calorimeter used is one based upon Thompson's method, and by being careful to maintain a uniform rate of combustion when burning the coal, close results can be obtained. The bomb calorimeter is better fitted for use in the laboratory than for general engineering work.

In passing, it may be stated that the burning in the oxygen calorimeter of certain classes of fuel, very rich in volatile matter or containing a large per cent. of moisture, is attended with much difficulty. Especially is this the case with peat, the lignites and the long flame bituminous coals of Wyoming and other localities. With the two latter it is generally necessary to mix with the sample to be tried a certain percentage of some coal containing a greater amount of carbon, and whose heating value is known.

Of course, the heating value of the fuel could be approximately determined from the proximate analysis by empirical formulæ. But as most of such formulæ are based upon the average amount of hydrogen in the volatile matter being 4.2 per cent. (which is the average in the bulk of American soft coals), they fail to give proper results when there is a larger per cent. of hydrogen. In the Alabama coals, for example, the hydrogen in the volatile matter averages over ten per cent.

A nearer approximation to the heating value could be obtained from an ultimate analysis of the coal by using DuLong's or Mahler's formulæ, but ultimate analyses are not always practicable.

Coals containing a high per cent. of volatile matter, and consequently showing comparatively high heating values by experiment and calculation, are misleading in estimating results. For some reason not yet determined, only a small per cent. of the heat contained in the volatile ingredients is utilized in the furnace. With a deep red flame and smoke, they slip up the chimney without doing the proper work. Especially is this the case in coals containing a large per cent. of hydrogen, such as the Alabama coals referred to. While the heating value of the hydrogen is very high, it manages to get away without yielding much of its power to the furnace. Even experienced engineers have been disappointed at the small results in evaporation obtained from such coals, where the calculated heating values were very high. For example, the theoretical evaporation of the best Alabama coals averages 15 pounds of water, from and at 212 degrees, per pound of coal. Some of the best boilers in the market have failed to secure an evaporation of more than from 9 to 9¼ pounds

of water, from and at 212 degrees, per pound of coal. Many boilers do not obtain 9 pounds.

In making the proximate analysis, close attention should be given to the rapidity of ignition of the coal, to the length of time the volatile flame is burning off, to the peculiarities of the carbon button, and also to the color and peculiarities of the ash. All such data are clues to the method of burning in the furnace, whether to keep the fire heavy, medium or light, whether to force or to burn slowly, whether to check or to increase the draft.

Much can also be learned from the appearance of the carbon button that is left in the crucible after burning off the volatile matter. The lignites and the hard anthracites leave no indurated residuum, but the residuum, after burning off the volatile matter, looks somewhat similar to the original sample. The coals of West Virginia, especially the Pocahontas and the New River varieties, leave a large porous residuum, or coke, that is much swollen. Indeed, this is a characteristic of most of the soft friable coals. The bituminous and semi-bituminous coals of Pennsylvania also leave a porous residuum, but not so large or so swollen as the West Virginia coals.

The coals of Ohio leave a button somewhat porous, but not so large as the Pennsylvania coals. The coals of Illinois and Iowa (the latter a most inferior coal) leave a hard, flat, metallic-looking button. There is one variety of Colorado coal that leaves a large porous coke, very similar to that of West Virginia. This indication, in the Colorado coal is apt to be misleading, for it is a much inferior coal to either the Pocahontas or New River. This is indicated by the fact that the coal referred to contains only about sixty per cent. of fixed carbon. As a rule, the large porous cokes indicate the quality of the coal as being of the best semi-bituminous variety with from seventy to eighty per cent. of fixed carbon.

In general, with coals containing as low as fifty per cent. of fixed carbon, a well designed boiler should develop an efficiency of seventy per cent. Below fifty per cent. fixed carbon only the best boilers with the greatest care and management of the fires, will show an efficiency of seventy per cent. By efficiency is meant the

number of heat units in the amount of water evaporated from and at 212 degrees divided by the heat units per pound of fuel.

Automatic stokers are great aids in securing good evaporative results. In such cases the necessity for frequently opening the furnace doors is avoided and much loss of heat is prevented. The Acme, Roney, Murphy and Mizner are good examples of such stokers.

Furnaces of the Hawley down-draft type are most excellent for the inferior grades of coal, or for coals containing a large percentage of volatile hydro-carbons. The gases, when first released from the coal, pass through the first fire to and over the secondary grate which is covered with incandescent coal, thus insuring better combustion.

The following table gives the average amount of volatile matter and of fixed carbon in the best varieties of the bituminous and semi-bituminous coals from the localities specified:

	Volatile matter.	Fixed carbon.	Heating value B.T.U.
	Per cent.	*Per cent.*	
Pennsylvania	27.40	64.00	13,000
Maryland	17.70	73.26	13,500
West Virginia	19.50	75.08	14,000
Ohio	35.82	53.50	12,500
Indiana	44.00	48.00	13,000
Illinois	36.08	50.00	11,000
Colorado	32.08	58.34	12,000

The foregoing are, as stated, simply general averages, given for the purpose of comparison of the relative values of the coals of the different States.

The allowance for moisture in coal, when calculating results of tests, frequently leads to much controversy. The distinction between "dry coal" and "commercially dry coal" is often very fine, but it should always be made. There should be no question of deducting the moisture from coals mined from wet mines or coals that have become wet from extraneous causes, but many engineers, in their zeal to secure good results, frequently make deductions for moisture when the moisture should not be allowed to apply on the commercial results.

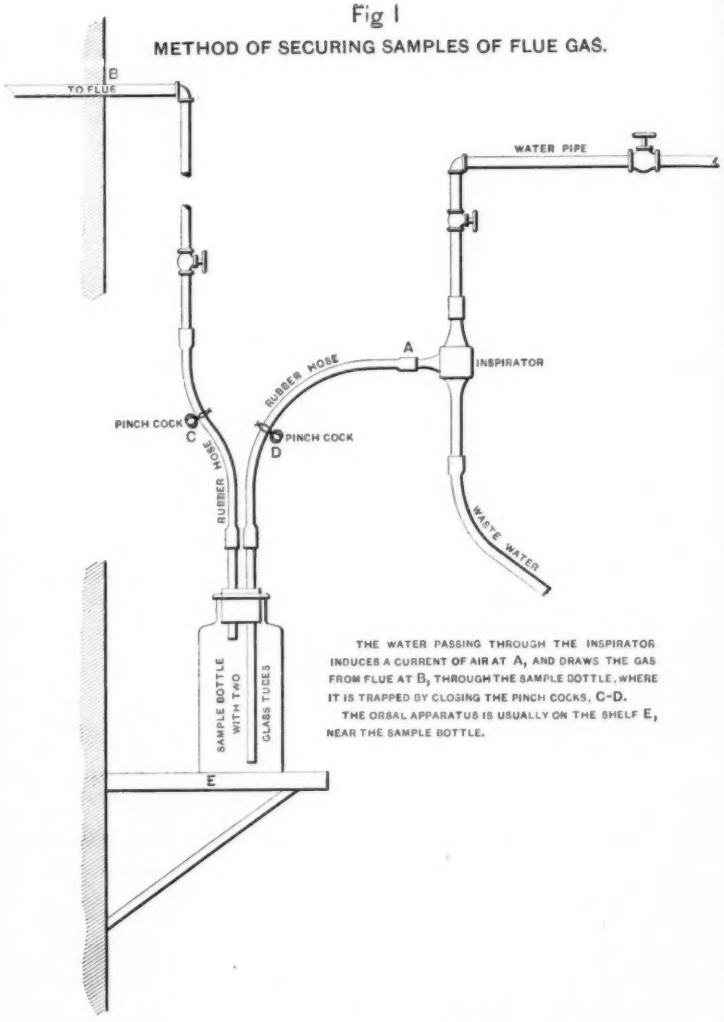
Much misunderstanding could be avoided if contracts involving the sale and testing of boilers were made more specific and explicit in reference to the fuel used. It must be understood that the foregoing remarks have reference to the commercial bearing of the results.

The method of starting and stopping the test is of vital importance. The usual or standard method reported to the American Society of Mechanical Engineers many years ago, and confirmed by the Committee on the Revision of the Code for Testing Boilers in a late report, directs that the fires be hauled and started afresh. This, in the opinion of the writer, is not the best method to secure the most reliable results, nor is it good for the boiler. The immense loss of heat due to the rush of cold air into the furnaces and connections while the fires are being hauled cannot be measured, while the shock to the boiler itself must be most injurious. The experience of the past few years has pointed out to engineers the best way to preserve boilers. Suddenly hauling the fires, even if they are immediately relighted, is certainly not among the prescribed rules of treatment for the better preservation of boilers. While it is true that this would not be a constant practice, nevertheless it would take any boiler a long time to recover its normal condition to make steam as it should after hauling the fires. From close observation, in a number of cases, the writer has discovered that when starting a test by the method of hauling fires, it has taken the boiler from two to three hours to recover its normal condition, or condition existing previous to hauling. If at all permissible, it should only be with tests of long duration.

The method of starting usually pursued by the writer is the "alternate method." In this case, the fires are well cleaned before the test, and allowed to burn down until they are quite thin. They are then "judged" by one or more observers. Before the end of the test they are again cleaned, and at the end of the test they are allowed to burn down to the same condition as existed when the test was started. The object of having the fires thin, is so that any error, even from faulty judgment, will be but slight. Indeed, in any case, the error must be much less than the un-

Fig I

METHOD OF SECURING SAMPLES OF FLUE GAS.



THE WATER PASSING THROUGH THE INSPIRATOR INDUCES A CURRENT OF AIR AT A, AND DRAWS THE GAS FROM FLUE AT B, THROUGH THE SAMPLE BOTTLE, WHERE IT IS TRAPPED BY CLOSING THE PINCH COCKS, C-D.

THE ORSAL APPARATUS IS USUALLY ON THE SHELF E, NEAR THE SAMPLE BOTTLE.

measured loss caused by the rush of cold air and the checking of the evaporation due to hauling fires.

In all, or nearly all, tests conducted by the writer within the past three years, the uniform practice has been to take frequent samples of the flue gases and analyze them. It is very easy to fit a sample pipe in the uptake and, by means of a small aspirator, draw off samples as needed. By doing this, and analyzing the gases promptly, any irregularity in the combustion, or anything abnormal, is at once detected. The samples can be quickly drawn, and it does not take very long to make the analyses. Fig. 1 will show a simple method of extracting samples of flue gas. For the purposes of the practical engineer, the Fisher's Orsat gas apparatus is undoubtedly the most convenient, if not the best, as it can easily be carried from place to place. In getting the draft or fire room pressures, a differential draft gauge is preferred to the ordinary draft gauge. Of course, in using the differently colored liquids in the differential gauge, care must be taken to have the liquids of nearly the same specific gravity. Kerosene, and alcohol colored by carmine, are excellent liquids for this purpose. It is always best to standardize the differential gauge frequently by a standard water gauge. Especially must this be done when the liquids are changed. It need hardly be said that the differential gauge is much easier to read than the ordinary water draft-gauge.

In making tests, it is well to take the draft at the furnace door, as well as at two or three different points in the connections between the furnace and the uptake. Any serious variation in the diminution of the draft from the furnace to the uptake or base of the stack at once indicates some abnormal condition.

In large cities, where municipal ordinances impose penalties upon excessive smoking of boiler chimneys, boiler or furnace manufacturers give guarantees that the operation of their furnaces or boilers will not produce smoke. Legal contests frequently result from such guarantees. A good plan for the testing engineer to follow is to take periodic kodak views showing the top of the stack and the volume of smoke. Where this is impracticable, an excellent method is to use charts with a number of squares, shaded

and numbered according to the density of the smoke. The observer can then enter such numbers in his log as may be indicated by the smoke from the stack, compared with the chart.

Finally, in coal tests, as in tests with all other fuels, especially where financial disputes may be involved, it is well to remember that voluminous data are not a fault, and the record of comparatively unimportant observations may have a decided value in any legal complications that may result between the manufacturer and the steam user.

OIL AS FUEL.

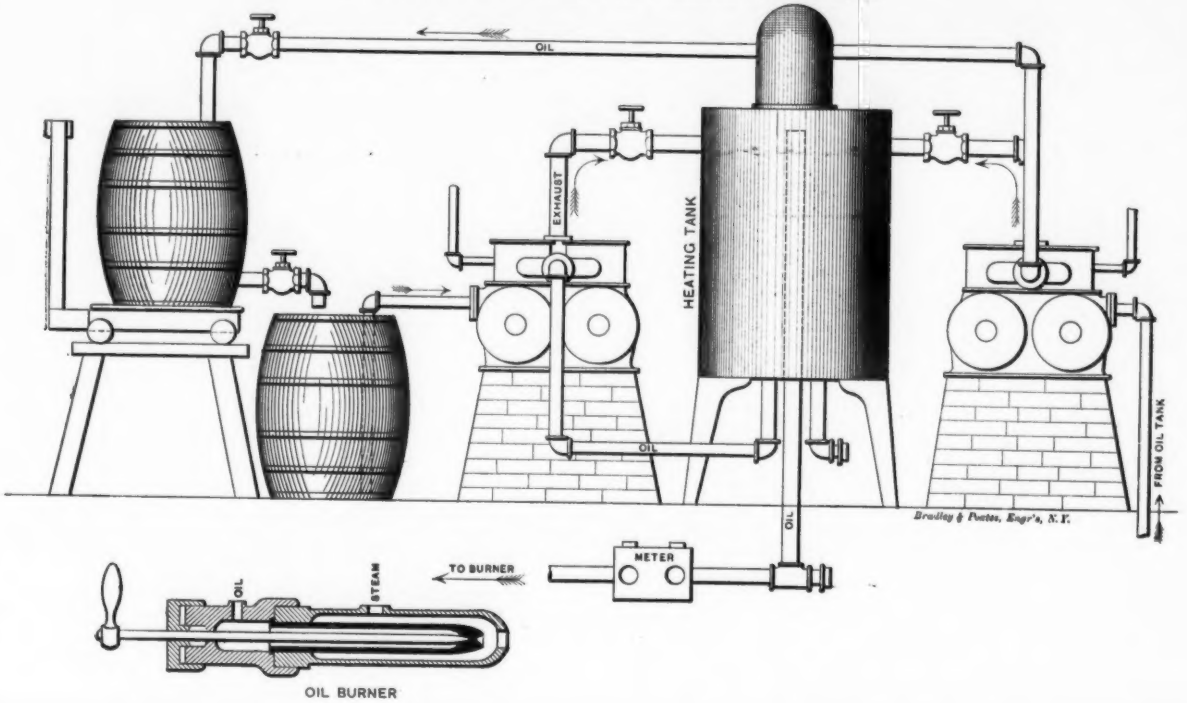
In burning oil as fuel under boilers there is a large variety of burners for spraying the oil. The ordinary double nozzles, such as the Reed burner or the Browne oil burner, using steam to spray the oil, are among the best. The system of the National Supply Company, of Chicago, is also an excellent method of feeding the oil to the burners. In this system the oil is pumped into a tank filled with tubes, through which steam circulates, heating the oil. The oil in this heater tank is under pressure, and this pressure can be regulated at will by the oil pumps. By this method the pressure at the burners is also regulated. The connecting pipes at the burners are, of course, fitted with valves, in order to regulate the relative supply of oil and steam or air.

In running tests with oil as fuel, the surest plan to determine the quantity of oil burned is by weighing. In the system referred to above it can easily be arranged to first weigh the oil, then afterwards pump it through the meter. (See Fig. 2.) By this means the meter is calibrated. In general, the meters record less oil than what passes through them, although, in a prolonged test on some Stirling boilers at the power house of the West Chicago Street Railway Company, it was found that the meters recorded six per cent. more oil than what actually passed through them.

The relative proportions of oil and steam can easily be regulated by the general appearance of the flames as they strike the targets and also by observing the appearance of the jets at the noz-

Fig. 2

METHOD OF WEIGHING OIL AND FEEDING TO FURNACES



zles. When proper combustion is taking place there should be no indications of black streaks from the nozzles of the burners. Observations of the smoke stack will also indicate proper or improper combustion, for when the oil is being properly burned there should be no smoke. The appearance of smoke shows that the oil is not being properly consumed. In this connection, it is curious to notice the difference between two oil firemen, both good. One will regulate the burner valves so as to give a clean, sharp, cutting flame, while the other will secure an intense, mellow flame, both apparently giving equally good results.

During such tests careful observations should be taken of the flames in the different flue connection passages in the boilers. Such observations are great aids in securing the best combustion.

It seems hardly necessary to mention that where oil fuel is used care must be taken to see that the flames from the burner nozzles should not be allowed to impinge directly upon the boiler tubes. Targets for preventing this and distributing the flames can easily be made of firebrick or tiling.

In determining the efficiency of the boiler the heating value of the oil must, of course, be ascertained. This can only be accomplished by analysis, as up to the present time there seems to be no successful method of determining the heating value by the oxygen calorimeter. The average results of the analyses of many samples of oil used by the writer in testing are as follows:

	Per cent.
Carbon,	85.20
Hydrogen,	11.78
Oxygen,	3.05
Heating value, B.T.U.,	19,437

In general, the heating value of most fuel oil varies from 19,000 to 21,000 B.T.U.

In tests using oil as fuel, the writer has, in tests of eighteen hours' duration, secured an evaporation of 14.89 pounds of water, from and at 212 degrees, per pound of oil.

In conclusion it may be stated that, in addition to the data usually recorded in boiler tests, the following should not be neglected:

1. Temperature of the oil in the heating tank.
2. Pressure of oil at the burners.
3. Specific gravity of the oil.
4. Samples of the oil for analysis.

No. 2 is most useful in making comparisons, and may indicate the cause of faulty combustion.

USING WASTE GASES OF BLAST FURNACES AS FUEL.

In conducting tests using waste gases of blast furnaces as fuel, it is well to remember that abundant data can never be a fault.

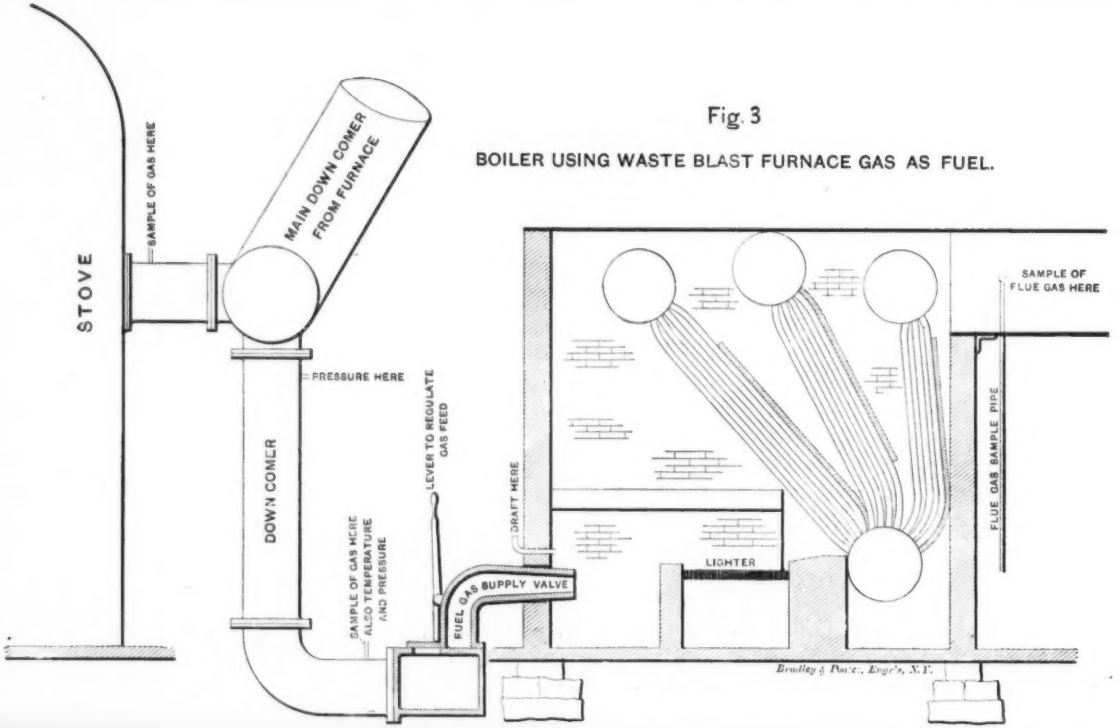
Besides ascertaining the evaporative efficiency, one of the great points in such tests is to measure the amount of the fuel gas sent into the boiler furnaces. Another necessity is to ascertain, by analyses, the component parts of the gas, in order to determine its heating value.

The measurement of the volume of fuel gas entering the furnaces is obtained by taking the pressure of the gas (in inches of water) at the upper end of the down comer to the boilers, also taking the pressure near the burners, as well as the draft at the entrance to the boiler furnace. The temperature of the gas as it enters the furnace must also be taken. From these data the volume of the gas can be computed, or the volume can be easily ascertained from a Cook's chart. This chart is based upon Napier's formulæ for flow of gases and gives close results. In ascertaining these pressures, in inches of water, it is best to use a differential gauge, for the reasons given in the earlier part of this paper.

The volume of air entering the furnace to unite with the carbonic oxide can be ascertained from knowing the size of the air openings and calculating the volume, being sure to secure the other necessary data, that is, the barometric pressure and the pressure in the furnace. The use of anemometers to ascertain the volume of air is not to be commended, as they do not record the full amount of the flow.

Fig. 3

BOILER USING WASTE BLAST FURNACE GAS AS FUEL.



In determining the character of the fuel gas, a sample pipe should be fitted into the lower end of the down comer, just before it reaches the gas ducts leading to the furnace. Another sample pipe for the flue gas should be fitted in the uptake of the boiler. Both these sample pipes should be connected with aspirators, whose action will draw the gas into the sample bottles. Samples of the fuel gas and of the flue gas should be taken simultaneously, and analyzed without delay. As many samples as possible should be taken during such tests. Fig. 3 will give an idea of the method of burning this gas.

The sample of fuel gas should show from twenty-five to twenty-eight per cent. of CO, this being the heating constituent of the gas. The flue gas should show a percentage of CO_2 (18.5 per cent. is a good average), and, with perfect combustion, there should be no CO. Traces of CO, however, generally exist.

From the samples of fuel gas, its heating value can be calculated. It must not be forgotten that, in order to secure the heating values, the percentage of the constituents in the gas must be reduced from the per cent. by volume obtained from the analysis to the per cent. by weight. This, of course, can easily be done by ascertaining the atomic weights of the different constituents.

The flue gas analyses will indicate the character of the combustion, and enable the engineer making the test to adjust his fuel gas and air supply so as to give the best results.

In burning such gases under boilers the gas generally enters the furnace a little above the grate bars. There are air passages around the gas ducts to permit the necessary air to enter, so that its oxygen can combine with the CO.

Upon the grates a small fire, called the "lighter," is usually kept burning, so as to ignite the gas as it enters the furnace and take up the necessary oxygen. Usually this small fire is not necessary, except immediately after the "casts" from the blast furnace are made. During the period of the "cast," generally about thirty minutes, no fuel gas is admitted to the boiler furnace, as the blowing engine is stopped and the gas valves to the

boiler furnaces are, or should be, closed. This is done to prevent any gas that may be in the down comer, leaking into the boiler furnace. When the "cast" is over, the blowing engine started, and the gas valves to the boiler furnaces are opened, care must be taken to see that the "lighter" is in condition to ignite the fuel gas at once, otherwise the accumulation of gas might lead to an explosion. During the progress of a test the furnace and connections of the boiler should always be carefully watched to see that there is no secondary combustion.

In working out results for tests, it is usually customary to express the heating value of the gas as so many thermal units per pound, or per cubic foot, then reducing the same to its equivalent of a coal of known heating value, the coal used in the "lighter," for instance. The following form of expressing results is one pursued by the writer:

Cubic feet of gas equivalent of one pound of coal, .
Cubic feet of gas equivalent of one pound of combustible, ...
Total fuel—gas equivalent of coal, plus coal used in "lighter," . . . . . .
Total fuel—gas equivalent of combustible, plus combustible used in "lighter," . . . . . .
Cubic feet of gas equivalent of one ton coal, . .

The above should, as is usual, be reduced to hourly quantities.

An average of fifteen samples of fuel and flue gases gave the following results:

	Fuel gas.			Flue gas.	
	By volume.	By weight.		By volume.	By weight.
CO_2.	7.16	10.88	CO_2.	17.14	24.33
O.	0.50	0 54	O.	6.12	6.32
CO.	26 63	25 51	CO.	0 76	0.68
N.	65 65	63.07	N.	75.98	68.67

The heating value of the fuel gas being 4,380 (Silberman & Favre) $\times$ 25.5 = 11,187 B.T.U. per pound of gas. To this must be added the heat due to the difference between temperature of fire room and temperature of entering gas 520° — 70° = 450 $\times$ .24 (specific heat of the gas) = 108 B.T.U. Total heating value of pound of gas = 11,295 B.T.U.

In conducting such tests the following data should be taken in order to determine conditions and results. These data, it must be understood, are in addition to the data usually taken in conducting ordinary boiler tests, using coal as fuel.

1. Pressure in down comer, in inches of water.
2. Pressure in boiler furnace.
3. Temperature of entering fuel gas.
4. Samples and analyses of fuel gas—these should be frequently taken.
5. Samples and analyses of flue gas—same number of samples as of fuel gas. (Nos. 4 and 5 should be taken simultaneously.)
6. Sample and analysis of gas at top of blast furnace.
7. Sample and analysis of gas in stove.
8. Temperature of gas at top of blast furnace.
9. Area of fuel gas duct opening to boiler furnaces.
10. Area of air opening to boiler furnace.
11. Area and length of down comer.
12. Character of fuel used in blast furnace.
13. Duration of the "casts."
14. Production of metal in the furnace per ton of fuel.
15. Amount of coal used in "lighter."
16. Heating value of coal used in "lighter."
17. Amount of production of metal from blast furnace per ton of fuel.
18. Kind of fuel used in blast furnace.

No. 7 is valuable as indicating any changes in the character of the gas.

Much valuable information on this subject can be obtained from an article written a few years ago by Professor Jacobus, entitled "The efficiency of a steam boiler, using waste gases of blast fur-

naces as fuel," published in the Transactions of American Society of Mechanical Engineers.

The above data will materially aid in drawing conclusions as to results.

USING BAGASSE AS FUEL.

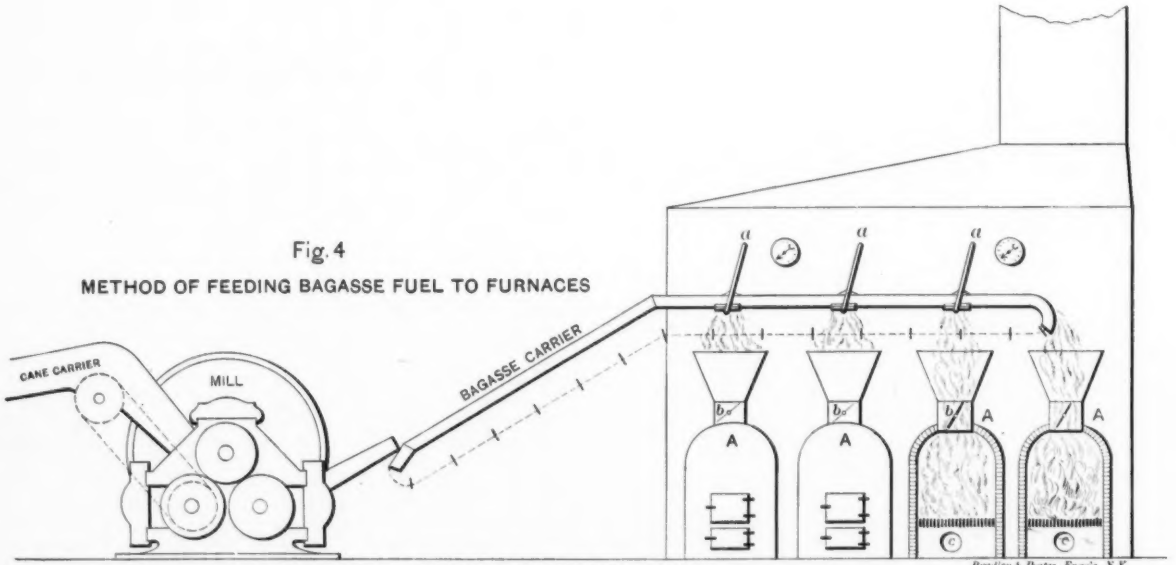
Bagasse is the residuum of ground sugar cane. There is diffusion bagasse and mill bagasse, depending upon the methods used in extracting the sugar juices. Mill bagasse is now being extensively used as fuel by the Louisiana sugar planters, who find it an excellent and economical substitute for the expensive coal fuel formerly generally used. Of the bagasse there are two varieties, the bagasse ground from stubble cane, and the bagasse from seed cane. Stubble cane is the cane raised from the stubble of the previous year. Seed cane, as its name indicates, is raised from the seed. The fuel value of the stubble cane bagasse is greater than that of the seed cane bagasse, as it contains more woody fiber. It is but a short time since engineers have been investigating the burning of this fuel. Among the first was Prof. R. T. Burwell, who read a valuable paper on the subject before the Louisiana Sugar Planters' Association, March 12th, 1896. This paper is well worth perusal.

Boilers using Bagasse as fuel have exterior furnaces, either with closed ash pits or hollow grate bars, as this fuel is best burned with forced draft. As the bagasse is ground in the mill, it is moved on carriers from the mill to the furnaces into which it is dropped through hoppers fitted with automatically moving covers. With the present arrangements in use, the fuel is dropped on the grate bars in the form of a cone, and is spread over the entire bars by the fireman as occasion demands. (See Fig. 4.)

In this connection it may be remarked that it is the tradition and practice of many bagasse firemen, and of some engineers in the sugar district, who ought to know better, that the best way to burn this fuel is to leave it undisturbed in the form of the cone or pyramid as it drops from the feed hopper. It is difficult to impress them with the fact that a more even distribution over the grates, and covering unsuspected air holes, is the best method

Fig. 4

METHOD OF FEEDING BAGASSE FUEL TO FURNACES



a a a—LEVERS TO REGULATE FEED OPENINGS
b b b—AUTOMATIC DOORS TO CLOSE OPENINGS TO FURNACES
c c—AIR DUCTS
A A A A—ARE PROJECTING OUTSIDE FURNACES

of firing. Undoubtedly their way has the merit of being much less laborious.

The imperfect combustion of bagasse is easily detected by the presence of smoke from the stack. With good combustion there is little or no smoke. It is a fair grade of fuel, and leaves a packed or indurated ash that forms in masses and is often very difficult to remove from the furnaces. When first started into the furnaces, the bagasse has to be ignited from a wood or other fire, but once under way it needs no aid, except at the intervals of cleaning fires, this cleaning being necessary about every eight hours. To properly clean, everything should be hauled out of the furnace. During this interval of cleaning the supply of bagasse fuel is stopped by being diverted to some of the other furnaces. After such cleaning a little wood is generally needed in the furnace to ignite the bagasse. If the cleaning is done quickly, however, there is often heat enough in the brick furnace arch to ignite the bagasse without using wood. A record of the weight of wood when so used, should be kept to be added to the fuel account.

In running tests using this fuel, one of the difficulties is to secure an accurate record of the amount of fuel used, without interfering with the operation of the sugar mill. To attempt to weigh the bagasse as it comes from the mill, especially in tests of long duration and with large plants, would be a perplexing and laborious task, as the amount used per hour may amount to several tons. The volume of bagasse is comparatively large per unit of weight, and as there must be no diminution or stoppage of the feed from the mill, it would require, in a plant of large capacity, a considerable force of men and teams for the work. Besides, the conditions of burning the bagasse would be changed from the normal method, as during this process of weighing the bagasse would be drying, thus giving higher results than in every-day practice when it is fed from the mill direct to the furnace.

The usual and most convenient method of arriving at the quantity of fuel consumed, is to carefully weigh the cane before it is ground in the mill. From this weight must be deducted

the amount of juice extracted from the cane. The amount of this juice or "extraction" as it is called, is always carefully recorded by the chemists and officials of the mill. In passing, it may be stated that the general average of extraction is something over seventy-six per cent.

In starting tests using bagasse fuel, the standard, or fire hauling method, can be used without the great losses attending such a method with coal fuel. The bagasse is easily hauled out, and the kindling of the new fuel is almost instantaneous, so that the loss by the inlet of cool air is not so great as that due to cleaning coal fires. But even in burning bagasse, the "alternate" method of starting is to be preferred, and should be employed whenever practicable.

In running such tests, especially for capacity, the duties of the supervising engineer are many and varied. The cane must be promptly weighed, and, as there is a constant stream of wagons and tram cars hauling the cane it needs persistent watchfulness. The furnaces, although automatically fed, must be carefully watched, to prevent choking or burning out, the latter due to some stoppage of the mill, the former to the irregularity of the feed. These disturbances are usually counteracted by a variation of the air blast in the furnace which can be regulated by the blower engine. Should there be a stoppage of the mill, it means the stoppage of the fuel supply, and it takes but a few minutes for the fire to burn down to the grates. In such cases, as indicated, a reduction of the air blast in the hollow grates or ash pits must immediately be made. These details may seem unimportant and easily carried out, but it must be remembered that the mill, except for the accidental stoppage mentioned, keeps at work, and the train of fuel is never ending.

As mentioned before, bagasse as fuel is coming into general use on the sugar plantations. Boiler makers and planters are beginning to learn that large furnaces and increased grate surface are decided factors in securing higher economic results. Some of the most successful boilers using this fuel have a ratio of heating surface to grate of about 36 to 1. Formerly the average ratios were from 46 to 50 to 1.

Molasses also has a fuel value, and, when low prices for it prevail, it may be burned in the boiler furnace with economy, providing some inexpensive way can be employed to spray it by using compressed air. There is too much water in the molasses itself to employ steam for the purpose of spraying.

The great source of loss in burning bagasse is its excessive moisture, the evaporation of which means a loss of heat. There is financial success for the engineer who can devise some economical means of drying bagasse while it is en route from the mill to the furnaces. The same remark can be applied to peat and tan fuels.

The heat constituents of bagasse consist of fiber, sugar and molasses. The approximate amount of moisture in bagasse of seventy-five per cent. extraction is fifty-one per cent. The fuel value per pound of fiber is 8,325 B.T.U.; of sugar, 7,223 B.T.U.; of molasses, and dry matter, 6,956 B.T.U. An average pound of bagasse of seventy-five per cent. extraction contains water, fifty-one per cent.; fiber, forty per cent.; sugar, six per cent., and molasses, three per cent. The heating value of one pound of dry bagasse of this extraction is, therefore, 3,972 B.T.U. As it requires about 15.4 per cent. of this heat to evaporate the contained water, the effective heating value is 3,361 B.T.U., making one pound of coal, of a heating value of 13,500 B.T.U., equal to four pounds, approximately, of dry bagasse. The heating values given for the fiber, sugar and molasses are from calorimetric tests made by Dr. Atwater.

Some determinations recently made in a Mahler calorimeter by Professor Magruder, Ohio State University, upon bagasse containing 44 26 per cent. moisture gave a heating value per pound as 4,535 B.T.U. This heating value, considering the difference in amount of moisture, is not far different from the values determined by Dr. Atwater.

Professor Burwell gives the results of some analyses of several samples of dry bagasse as follows:

Volatile matter per cent., ...	81.37
Fixed carbon, per cent., ...	14.03
Ash, per cent., ...	4.60

FORM FOR REPORT OF BOILER TESTS.

Report of boiler tests made at.....

For.....

	Date of Test.	Date of Test.
Kind of boiler.....		
Dimensions.....		
Stack.....ft. high, ...sq. ft. area..		
Duration of trial, hours.....		
Grate surface, sq. ft.....		
Water-heating surface, sq. ft.....		
Ratio—Grate to heating surface.....		
Average Pressures.		
Barometer, ins.....		
Steam gauge, lbs.....		
Draught gauge, ins. water.....		
Average Temperatures.		
External air.....		
Boiler room.....		
Escaping gases.....		
Feed water		
Fuel.		
Kind of fuel.....		
Specific gravity.....		
Cost		
Total fuel used, lbs.....		
Per cent. wet.....		
Dry fuel, lbs.....		
Total ash and unburned fuel, lbs...		
Per cent. ash.....		
Total combustible, lbs.....		
Fuel per Hour.		
Fuel per hour, lbs.....		
Combustible per hour, lbs.....		
Fuel per sq. ft. grate, per hour, lbs..		
Fuel per sq. ft. H.S., per hour.....		
Fuel per horse power, lbs.....		
Water.		
Total water used, lbs.....		
Per cent. of moisture in steam.....		
Quality of steam.....		
Total water exaporated into dry steam.....		
Total water evaporated into dry steam from and at 212°		
Factor of evaporation.....		
Water per Hour.		
Amount used, lbs.....		
Evaporated, dry steam, lbs.....		
Evaporated from and at 212°, lbs..		
Evaporation		
Per lb. Fuel.		
Actual evaporation, wet fuel.....		
Actual evaporation, dry fuel.....		
From and at 212°, lbs. dry fuel		
Per lb. Combustible.		
Actual evaporation, lbs.....		
From and at 212°, lbs.....		
Per Sq. Ft. G.S., per Hour		
Actual evaporation, lbs.....		
From and at 212°, lbs.....		
Grate surface per H.P., sq. ft.....		
Per Sq. Ft. H.S., per Hour.		
Actual evaporation, lbs.....		
From and at 212°, lbs.....		
Heating surface per H.P., sq. ft.....		
Horse Power.		
On basis of 34½ lbs. per hour, from and at 212°.....		
H.P. developed during trial.....		
Per cent. H.P. developed above rating.....		
Proximate Analysis of Fuel.		
Water / Vol. Matter / Fixed Carbon / Ash		
Heating Value of Fuel.		
Heating value, calculated from analysis.....		
Heating value, by oxygen calorimeter.....		
Heating value of combustible (ash.....)		
Heat absorbed during evaporation..		
Efficiency of boiler		
Flue Gas Analysis.		
Carb. Acid / Oxygen / Carb. Oxide		
Cost of Evaporating Water.		
Actual cost evaporating 1,000 lbs water.....		
Pounds water evaporated for $1.00		

Some of the important data required in conducting tests with bagasse fuel are as follows:

1. Weight of cane ground.
2. Per cent. of extraction.
3. Revolutions of pressure blower.
4. Pressure, in inches of water, in hollow grate bars or ash pits.
5. Character of the cane, whether seed cane or stubble cane.
6. Pressure on mill rollers.
7. Periodical samples of the fuel kept in air-tight jars.
8. Determination of amount of water in bagasse.

Appended is a form of Commercial Report of Tests used by the writer. While lacking in the minuteness of detail used by many engineers, and so confusing to the layman, it embodies all that is necessary, especially from a commercial standpoint. The net results can be seen at a glance. It is applicable to most fuels.

Discussion.

P. A. Engineer W. M. McFarland, U. S. N.—The paper that Col. Jones has just read is a very valuable one, and it is a pleasure to me to acknowledge again my indebtedness to him for valuable information, inasmuch as my earliest engineering instruction came from Col. Jones when he was an instructor at the Naval Academy.

Now, with respect to what he says about the two methods of starting and stopping a boiler test, there can be no question that we all agree with him that it is not a good thing for a boiler to haul fires suddenly and start a fresh fire, and in this respect what he calls the "alternate method" certainly has an advantage. It seems to me, however, that we may recognize that there is a place for both the standard and the alternate methods. In the standard method we undoubtedly do get the amount of water evaporated by a given weight of fuel very accurately, and where that is the prime object of the test, it seems to me this method must be adopted. On the other hand, we all recognize that during the first hour the fires are burning up and getting in good condition, so that

the rate of evaporation, or, as Mr. Isherwood used to call it, the potential evaporation, is materially reduced, and, of course, at the end of the trial when the fires are burning down the same thing occurs. The result of this is that, if the boiler is guaranteed to give a certain horse power which is right up to the limit, and the trial is short, there might be a failure to attain the guaranteed figures, although in steady working the boiler could readily give them.

This very thing occurred in the trials of the Ward boiler in the competitive tests which led to its use on the *Monterey*. The average horse power for twelve hours, owing to the standard start and finish, was, as I remember, about 1,120 horse power; while deducting the first and last hours and taking the steady running for the interval, the horse power was about 1,300. I presume that an engineer experienced in judging the condition of a fire could make a test with a running start and finish extending over, say twenty-four hours, with a very small percentage of error, but, as I have already said, if the prime object of the test is to guarantee a certain evaporation per pound of coal, it would seem that the standard method would have to be adopted.

Mr. John Platt, Associate.—I would suggest that perhaps there is some degree of difference which should be exercised in making boiler tests on land and in marine service, particularly in the manner of starting the test. When one takes into consideration the fact that a land boiler will burn only from 10 to 12 pounds of coal per square foot of grate, and a marine boiler, when forced, burns from 50 to 60 pounds per square foot, it will be seen that it will make a great deal more difference to draw the fires and start afresh in marine than in land service. When water-tube boilers are being forced a flying start is likely to be the more reliable.

Col. E. D. Meier, Associate.—I entirely agree with Mr. McFarland, but I go further. I think what is known as the alternate method of conducting tests should be the only standard method. I remember a test I made once. The boiler was

placed in front of a steel heating furnace. I had a pyrometer placed at a distance of fully fifty feet from the door of this heating furnace counting by travel of the gases, and when the door was opened the pyrometer would immediately fall from 100 to 150 degrees. That shows how extremely sensitive a boiler furnace is to anything of that kind. Now the object of the standard system is to have nothing left to the judgment, and it leaves much more to the judgment, or rather to guess work, than the alternate method. The only proper way, to my mind, is to use what is known as the alternate system. Another thing I would like to say in regard to Col. Jones' paper, and that is that he has done a great service to the boiler men of the country in the testing of different fuels about which very little positive information is obtainable. A boiler maker can not make an honest guarantee of what a certain coal will do under his boilers unless he has the very facts which Col. Jones' paper now supplies.

SPEED OF CONSTRUCTION, A VITAL FACTOR OF NAVAL STRENGTH.

By Frank B. King, Esq., Associate.

It is always easier to indulge in general reflections than to confront the vexatious problems of detail immediately before us, yet broad considerations are sometimes in order, and on this occasion it seems desirable to invite attention to a widely discredited, yet most important feature of naval strength, pertinent indeed to all maritime nations, but having a special significance to the United States. While I must deal with the matter hastily, and without the systematic arrangement which lends an argument force, I hope to win just consideration of a case which has hitherto received such limited attention.

When the partisan of a strong foreign policy advocates the increase of the navy, he enlarges on the powerful armaments of other nations, tells how weak we are at sea, especially in battle ships, how long the period of preparation must be, and what years, what weary years, it takes to build a battle ship! The Nation accepts this opinion, because the world accepts it; but is it so? or rather, does it require such periods to build *effective* war ships?

Roughly, our recent record seems to run from three-and-a-half or four years on our battle ships, down to eighteen months or two years on gunboats of a thousand tons. This, in an era when "time has been annihilated by mechanism," suggests an epoch close at hand, when time considerations, no less than a due regard for simplicity and good sense, must annihilate the exuberant mechanical detail which seeks embodiment in our future vessels.

The most obvious way in which time could be saved in naval shipbuilding would be in general simplification of hull, machinery, fittings and, doubtless, of armament. There is in every navy

a powerful opinion distinctly in favor of such a step. The present Chief Constructor concludes his report on European dockyards, published in 1886, in these memorable words: "Such a war, or one such battle, would prove what has long been the apprehension of intelligent naval officers, that the war ship of our day has become far too complicated for the people who may be called upon to work her; and that a balance of advantage, unsuspected by many, rests with that vessel which has comparative simplicity, even though it be concomitant with a greater apparent exposure of life, a lower speed, and reduced powers of offence." In 1891 Lord Brassey, in a paper before the Institution of Naval Architects, quoted this portion of the report, and in the discussion which followed it was very warmly approved by several gallant admirals; and from "Engineering" we learn that naval opinion was strongly at one with the ideas set forth.

A very large time expenditure goes into the water-tight subdivision of the ship. The spaces are frequently so small that few men can be brought to bear on the work, and they labor under such physical disadvantages and such imperfect supervision that their output is exceedingly small; every compartment, moreover, has its inevitable train of water-tight doors, and drainage, and often ventilating appendages, all of which are insatiate consumers of time; so that every reduction in the number of compartments which can judiciously be made will be productive of material gain. The ventilating and drainage systems are hopeful directions in which to prune, and in the engine room the duplicate and triplicate methods of working auxiliaries, when not essential to prevent the vessel being disabled, might be wisely suppressed together with much general detail.

A great deal could be stripped off the ships as they stand, but there are organic modifications possible in new desings which will reward persistent study in this direction with larger economies of time.

If we glance for a moment at other lines of construction, we find that operations which formerly consumed years, are now better done in months, and in the manufacture of details days have been replaced by hours. Such works have grown in size

and elaboration relatively as ships have grown; the tall buildings, the bridges, the locomotives of to-day are but a few of the illustrations which must arise in every mind. Only a warship takes longer to build than ever before.

This facility in every-day manufacture is largely due to the substitution of metal for less manageable materials, yet the replacing of wood by steel has only increased the delay in naval construction. Will we, or any nation, fully learn the art of metallic ship building for the purposes of war until we take advantage of the rapidity with which an entirely suitable material may be furnished, and of its remarkably tractable nature to the speedy accomplishment of structural ends?

Again, facility in every-day manufacture has been amazingly increased by the development of tools; naval ship building has had a share of this advantage, but far less benefit than it might have if it could avail itself of another principle which, more than all else, has expedited ordinary construction. For want of a better name, we may call it the "unit principle."

Every steel framed building, every steel bridge, every order of locomotives is made up of great numbers of identical parts, designed, individually and collectively, to lend themselves to extreme celerity of construction. Even the minor details, the punching, riveting, drilling, etc., are wisely studied compromises between the absolutely just proportions and the most uniform, and therefore most rapid, shop practice. And in this lies the skill of the designer of such work, that while cognizant of the theoretical claims involved, he will not specialize, unless the nature of the case affords most cogent reasons.

But how may this "unit principle" be applied to creations of such marked individuality as war ships? In the first place, their individuality is largely the result of a too academic school of shipbuilding. Every officer who is entrusted with a design, or some portion thereof, has a praiseworthy impulse to improve on what went immediately before, and often feels ashamed to copy even a good thing. From his training he is most unlikely to give just consideration to uniformity of construction, especially as that has never been officially promulgated as a feature of our

shipbuilding policy. Our first effort must be to efface this undue specialization; but, with our minds once made up in this direction, we shall find that not only by building a number of vessels exactly alike shall we be able to multiply the units, but within the same vessel modifications of design can be worked out which tend to a large reproduction of identical parts. Of course, in the hull, this will occasionally call for a radical departure from what has been regarded as shipshape, beautiful or scientific; but what radical departures we have already seen from what was lately shipshape. How can anything be truly beautiful if antagonistic to its proper aim? And is not the most perfect engineering science only the well studied adaptation of means to ends? With the under-water form of a ship it is obviously impracticable to do anything radical, but why may not extensive changes be wrought in the upper works and interior, tending to reproduction of parts and simplification of work? If work can be expedited thereby, why should not great blocks of the plain and straight portions be given out to bridge or other shops, these portions to be only assembled at the shipyard? What are the possibilities of a system of permanent metallic templates, where a number of such vessels are in contemplation? What simplifications of plating and framing can be effected if we are willing to make a sufficient sacrifice therefor?

But in the machinery of a war ship the "unit principle" would find its largest application, and is, in a measure, already initiated. Our first twin screw ship was a step in this direction, though a short one. We have now ships having four engines identical, I believe, in all their parts. But the great excellence of the principle, as I view it, would manifest itself in connection with the division of the "passage" and "emergency" power of our ships, with which it is very closely bound up.

In discussion of Commodore Melville's paper on "Machinery of the new vessels of the U. S. Navy," read before the Society of Naval Architects and Marine Engineers in 1893, I said in part:

"But reflect that the emergency power in ships is now ten or fifteen times that which will allow them to cruise at nine knots, and will in the near future be twenty times, and that until very

recently the lower power has been developed in cylinders adapted to the higher power, and that nearly all the coal is burned at cruising speeds, and the enormous tribute paid to friction and condensation become manifest, as well as the fact that division of the power into two equal sets of engines on the same shaft, or three equal engines on three shafts, or any arrangement for shutting off certain cylinders for reduced power, as in the cleverly worked out scheme of gunboat *No. 7*, only attacks the great problem in a conservative way.

"I conceive that in the coming war ship we shall have entire dissociation of emergency and passage power for engines and boilers both. Probably we shall have, alongside of a propeller shaft, a double row of geared engines, the engines speeded faster than the screws. The first of the series, going forward along the shaft, will be the cruising engine, of durable construction, not too light, jacketed, arranged to superheat between the cylinders, with large ratio of expansion, and geared to run at a fairly high speed when the ship is going nine knots per hour.

"The boilers corresponding should also be designed to secure the highest economy, working with Howden or other heated forced draft, and automatic stoking to prevent the frequent entrance of cold air to the tubes and to secure the highest efficiency of combustion. This would constitute the cruising machinery and would be adapted to strain out the last dregs of work practically available.

"Passing forward from the cruising engine, we would come to the double row of emergency engines, of torpedo-boat design, geared to the propeller shaft at each end of their own crank shafts, with gearing perhaps of friction type, but preferably helical, I should think. The number and size of these units would depend upon stowage, speed of rotation and special considerations. I would have them of rather cheap construction, but everything likely to go wrong would be carefully reinforced and guarded. As they would run for emergency requirements only, or for drill, I would have pistons and piston valves without packing rings, and most of the arrangements fitted for taking up lost motion would be suppressed or replaced by bushings.

"All of the emergency engines, as well as the passage engines, would be arranged to disconnect from the propeller shaft; this would, of course, involve elaborate clutches.

"The idea is many sided, and may be approached in other ways; but the great principle of dissociation of passage and emergency powers will yet be worked out on radical lines. Nor can we forecast how great a radius of action may yet be given to our ships under steam alone, if the passage speed adopted is low enough and the passage engines are designed as indicated. Sails are out of the question for our modern ships. Steam should always be on for a hundred purposes beside propulsion. Spars are antagonistic to fighting efficiency. They have no apology for existence except when machinery is disabled; but the vessel under consideration has her power comprised in so many units that she can never be incapacited except through the exhaustion of her fuel.

"There remains one powerful argument for the machinery described—facility and rapidity of equipment. This element ought to enter into and dominate naval design, but is ignored the world over. What naval architect or naval engineer seeks to develop types in hulls or engines which will lend themselves to extreme celerity of construction? And yet such skill would be beyond price to any nation which must suddenly place itself on a war footing, or which must sustain a force at sea in the face of the rapid destruction of a naval war.

"This machinery could be built in the smallest marine shops; a number of small shops could be employed on the units which make up the power of one vessel, or the great locomotive shops, which attain such amazing rapidity of production where large numbers of like parts are required, could be engaged on the machinery of a fleet with surprising results."

If the Government owned the patterns and templates pertaining to such work and loaned or rented them to contractors, the results would be more uniform and construction would be greatly facilitated.

To briefly outline a system of rapid building, I would strip from our present designs everything which as a time consumer

or a complication a competent board may consider negligible. They should then classify the vessels to be built into certain standard designs, as few as possible, and prepare those designs, after prolonged study of the probable drift of naval development, with especial regard to the employment of the "unit principle," in general and in detail, devoting themselves also to those executive features which may expedite construction.

To this end they should somewhat relax our inspection of steel. Why were chemical requirements ever instituted except as a concession to our too academic methods? This matter closely concerns the steel maker, but is of remote interest to the steel user. We are not buying a fertilizer; and to ask a precise chemical constitution in a material whose function and supreme test are purely mechanical, is only a studied perversion of our ultimate interests. There is, possibly, a little better reason in prescribing the process by which such steel is to be made; but that, too, is immaterial if we secure the desired working qualities.

Then, Congress having made provision for a continuity of naval policy extending over a period of years, these designs would be offered to contractors, but only to such contractors as could demonstrate that they had not only the plant, but ample capital to carry on the work with due rapidity.

The designs must be so complete as to leave nothing for the contractor and resident inspector to haggle over; absolutely no ground for those interminable discussions which were for several years the bane of the author's life; and, as the scheme of each vessel is assumed to have been thoroughly digested at the Department, in general and in detail, the contractor takes it with the distinct understanding that there are to be *no changes*, unless in matters too trivial to affect the uniformity of the work in its bearing on prompt construction and rapid repair.

I would withdraw time penalties, which have been so unwisely instituted, or so unwisely condoned in the past, and, perhaps, speed premiums, in all future work, with the idea of offering a graduated, increasing bonus for fast construction, so large that the work would be much sought by competent contractors and avoided by the incompetent. In some measure these premiums

would be offset by money saved in mechanical redundancies stripped off our present type of ships.

These designs would then be built as if the "clash of arms was already in the air;" and, when that clash comes, they will be built a little faster still, as a result of the continuous training of all parties concerned; nor will the result be a haphazard one, such as now confronts us the moment we have to drop our deliberate and polished methods.

Who can set a value on this training from the designing staff down? We go to enormous expense to educate naval officers, and propose largely to increase our enlisted men; we take great pride in our naval militia, but we never think of the development of a class of men who can build a warship in the minimum of time. A gentleman, once prominent in the affairs of the Confederacy, assured me that to them one man in the shops was worth ten men in the field; I leave to your individual opinion how many men afloat may be equal to one man with the training I have described in the day of the Nation's agony.

To make this training more effective it might be found practicable to make the men participants to some extent in the high rewards which this class of work should hold out; and to further develop them and keep them together, naval work should not be recklessly distributed, but should go only to districts where such labor is to be found, or to those where it is of national importance that it should be developed; and in this connection, as well as to secure other advantages, it is deeply to be desired that the country should be pledged to a definite and continuous building program, however moderate.

The inspectors of the work must be chosen solely for their capacity to inspect, and not with the idea of completing their education. Few men are truly fitted for superintendents of either naval or merchant work. The arbitrary condemnation of material for insignificant defects, the wholesale rejection of work which has reached an advanced stage for faults which should have been detected long before, under an alert system of surveillance, can have no place under the proposed dispensation; but, on the other hand, in a ship built on these novel principles, inspection as to essen-

tials cannot be too severe; and, with a full knowledge of this fact on the part of the men, war ship building will be most wisely conducted, both for quality and speed, if, wherever practicable, it be made piece work.

Objection will at once arise against such rapid construction, that it will be very expensive for the results attained; again that the ships will be built so fast that it will be difficult to keep the men continuously employed. In reply to the first, if the vessels are designed for the highest rapidity of construction, they call for the minimum of labor; and that labor, though much more severe, will generally be somewhat less skilled than is now employed, and altogether not more expensive, especially in view of the result aimed at, which is of great national moment. In reply to the second, the manifest policy is to have fewer ships building at once, but carry them along at the highest practicable speed. Even though this policy results in training but a limited number of men, they, under a wise distribution in time of war, would be able to leaven an army of workmen with the principles on which such work must be conducted; and I conceive that it might be found feasible, as this matter developed in future years, to establish a national register of such men, accompanied by some appropriate distinction, resembling that of a naval reserve man in the merchant service of Great Britain.

It will be further objected that the scheme of standard ships at once shuts us off from the benefit of all new improvements. Look as far ahead as we will, and cut out our standards according to the most advanced fashion plates of naval tailors, still, it will only be a short time until they are all obsolete, and we will have nothing to oppose to the improved ships of other nations. But I have not implied that it would not be necessary to establish from time to time new standards to take account of the world's progress, or to embody what we learn about more rapid shipbuilding, if for nothing else. I merely contend that rapidity of construction should dominate naval design, and it demands that we shall make our advances in a series of long and well-considered steps, and not in efforts to meet every important foreign design by one of the same type a little better. We are

too ready, in these ultra-progressive days, to condemn things as obsolete; but there is this to be said about warships: We can do nothing that will tend more to render other navies obsolete than to confine our ships to as few classes as possible; have the units of structure, the units of power, the units of armor and armament identical in the same class, and, if possible, in several classes; have spare parts of all these units in stock, even to spare engines, for rapid repair; and an organized body of men in the country whose sole business is to build war ships with the utmost speed.

How often, even in time of peace, are we reminded of the fragility of the modern war ship, the mightiest, but for its size the most tender of the creations of man: then, how quickly, in a war between great naval powers, must whole fleets be destroyed when precipitated against each other by men of equal valor, impelled by equal national hate. Truly, we must not lean in fancied security upon our existing fleet. Though augmented to any probable extent, it is only to be regarded as the "forlorn hope" of battle; able, we trust, to inflict deep injury on the foe in the first grand onset, but doomed to be well-nigh obliterated in the attempt.

But some one will say that then we can knock out a makeshift ship as quickly as the enemy. It is precisely that makeshift vessel that I seek to eliminate; for God knows what it might be like. We had some makeshift ships built during the Rebellion; some that passed into history as "the totally submerged class of monitors." And, when we find ourselves suddenly involved in a desperate struggle, and panic reigns supreme, the reckless shipbuilding that may be authorized by the administration then in power will be only comparable to those idiotic acts which sometimes attend a country village fire. The ability to hustle effectively is not acquired in a day or year, though we can throw ourselves into a "fool's hurry" at any time. On the contrary, the more the matter is examined the more apparent it is that we are opening up a broad study that may well engage our best talent, both for design and organization.

It now only remains to invoke our deliberate and patriotic

judgment, not on this defective presentation of the case, but on its innate merits. The conclusion to me seems plain. All turns upon the purpose for which the taxpayers maintain this navy.

If its function is to awe weak nations and co-operate with strong ones; to form an inspiring marine picture as it floats off Old Point, so terrible, yet so shipshape and beautiful; to win the encomiums of foreign officers in grand reviews and naval pageants, as at the Baltic Canal, and New York in '93, then let the long and labored system of construction keep on.

But, if its function is to maintain the Monroe Doctrine over this continent and its contiguous islands, from Alaska to Cape Horn, against the aggression of any European or Asiatic power, however great, then, in the name of unnumbered heroes who braved death behind our simple wooden walls of the olden time, as well as in response to the truest impulses of professional pride, let us organize to build our ships with the utmost speed. Above all, let us develop a type of battleship consistent with this aim. To further ignore and antagonize the great study of emergency construction and repair in continued building of the overwrought ship of to-day is "dropping the bone" to follow merely a majestic "shadow" of naval greatness.

DISCUSSION.

Col. D. P. Jones, Member.—This paper is rather difficult to discuss, as it suggests a perfection in method of construction that is desired by all, but somewhat impracticable, unless all types of vessels were designed upon precisely similar models as regards their respective classes. Nevertheless, I wish to express my appreciation of the paper, which is a classic, and points out in an admirable way what is very desirable, even if impracticable.

P. A. Engineer Emil Theiss, U. S. N.—There is one point in connection with the admirable paper we have just listened to—which, no doubt, its author had in mind, but to which I would like to give more definite expression—and that is the

readiness with which the system of the multiplication of small engine units lends itself to their replacement and repair in time of need, as these small engines may be put in their places without the necessity of dismantling the ship to get them in. One of the points which has always been insisted upon as being one of the greatest advantages of tubulous boilers over Scotch boilers for marine purposes is this same readiness with which they lend themselves to their introduction into the ships, as they may be taken to pieces and assembled in place.

P. A. Engineer W. M. McFarland, U. S. N.—Mr. King's paper is very interesting, and I anticipated when he began its reading that he would refer to his plan of differentiating emergency and passage power, on which I had heard him speak some years ago in another society. The points he makes are certainly worthy of very careful attention, and there can be no doubt that they would contribute materially to the rapid building of vessels in time of war. I may say in this connection that this plan of building to standard sizes is now carried out in the Navy where applicable. Our steam launches are graded into certain sizes, with machinery of a certain kind for each particular size, and we manufacture the engines and boilers for these special sizes and keep them on hand, so that when a new outfit is needed we can telegraph, if necessary, and have the new machinery shipped so that it will go right in place of the old. I may remark, also, that in his last annual report the Engineer-in-Chief of the Navy called attention to the desirability of building ships in classes, although it was not altogether for the reason that Mr. King advocates, while it would work in with his views.

THE DIESEL MOTOR.

By Col. E. D. Meier, C. E., M. E., Associate.

If he who causes two blades of grass to grow where only one grew before is held to be a benefactor of his kind, is not a greater meed of praise to be his who makes one pound of fuel do the work of two? For grass will spring from the soil as long as air, water and sunlight exist on this planet. But our fuel supply is limited. Warnings have been uttered against its waste, and inventions multiplied for its economy since Watt first taught us how to transmute heat into dynamic energy.

For, since a scientific investigation of the working of the steam engine began, it has been apparent that it is sadly deficient in economy. Its great superiority over manual and animal power for a long time blinded practical men in regard to this question; but during the last thirty years all engineers have been on the alert to discover means to increase its economy. The power locked up in a pound of coal can be determined with considerable accuracy, both by chemical analysis and by practical experiment. And we must confess with some chagrin, that in the best types of triple expansion engines, supplied by the best boilers and managed with the greatest care, we can realize only about twelve per cent. of the potential force of the coal we burn, while in the ordinary engines in most general use in thousands of manufactories we must be satisfied with six to eight per cent.; and again, in many millions of small engines in use as auxiliary machines, such as steam pumps, etc., we realize hardly two per cent. of the heat available in the fuel. Improvements in boilers and furnaces have gone about as far as is possible, and these sources of power put as high as seventy-five and eighty per cent. of the fuel value into the main steam pipe. The balance of the enormous loss above quoted is in the engine itself. The sources of loss are well enough known, but the remedies can

not be supplied with the means at the command of the engineer. The larger amount of the loss is due to certain physical properties of steam. In the first years of this century, Sadi Carnot developed the theory of a perfect heat engine. This has since then been the ideal of mechaniçal engineers, and they have groped, in patience and in hope, in slow approach towards its perfection.

The great Ericsson, you will remember, attempted in the 50's to make a great stride forward by substituting air for steam. But he failed from a want of knowledge of many principles since then developed by the modern science of Thermo-Dynamics. In 1860 this science was hardly known by name in engineering schools. Now, it is the study of central importance for mechanical engineers.

Joule, Mayer, Hirn, Rankine, Clausius, Deschanel, Zeuner, Thurston, Peabody, are but a few of the men who, taking up the suggestions of Boyle, Mariotte, Humphrey Davy, Rumford, Gay-Lussac, etc., have given to practical engineers and mechanics the charts and beacons by which to steer on this new boundless sea.

The first attempts to obtain power from the explosive force of gases or oil vapors date from the end of the seventeenth century, and the names of Haute-Feuille, Huyghens and Papin are recalled as the pioneers in this work. Then the application of steam to this purpose so absorbed the attention of scientists and experimenters that nearly a century elapsed before another inventor entered the field.

In 1791 a British patent was granted to Barber for an engine worked by the force of burning gas directed against the vanes of a paddle wheel. Next came Street, in 1794, with an engine in which vapors of turpentine or petroleum mixed with air were exploded by ignition from an external flame.

In 1799, Lebon obtained a patent for a gas engine in which the gas, "with sufficient air to make it ignite," was compressed before explosion. The ignition was by electric spark.

The next partial success was Brown's engine, in the first quarter of our century, in which slow combustion of gas raised a piston and water spray produced a vacuum, and thus atmospheric pressure caused the power stroke.

In 1838 William Barnett invented three engines. In the first two a slightly compressed mixture of gas and air were ignited, while issuing from a receiver, and burned in the motor cylinder at constant pressure. In the third engine the mixture was compressed in the motor cylinder itself and exploded at the beginning of the return stroke. In his engine he used an ingenious igniting cock, inside of which a gas jet was alternately lit by an outside burner and blown out by the explosion. His precompression and explosion at the dead point are used in nearly all modern gas and oil engines.

In 1843, Dr. Drake, in Philadelphia, exhibited a gas engine in which the proper proportioning of the mixture and hot-tube ignition were the principal features. In 1857 Barsanti and Mateucci built the first free-piston engine, in which the explosion throws up a heavy piston, and the returning weight and a partial vacuum, by means of ratchet and pawls, transmit motion to a shaft.

This closes the experimental stage of these motors, and in 1860 Lenoir, in Paris, brought out a successful type, of which many were built. They take in gas and air at atmospheric pressure and explode by electric spark. Lenoir believed that a slower explosion would increase his economy, and even proposed stratification of the charge.

Dugald Clerk says: "It is somewhat extraordinary to find notions so erroneous common at a time when Bunsen's work had clearly proved the continuous nature of the combustion in gaseous explosions, and when Hirn had made experiments which showed that the heat evolved by explosion in a gas engine was only a small part of the total heat of the combustion, the heat which did not appear during explosion being produced during expansion.

Other speculations on the cause of the uneconomical working of the engine were frequent, but the true reason was fully explained by Gustav Schmidt in a paper read before "The Society of German Engineers" in 1861. He states: "The results would be far more favorable if compression pumps, worked from the engine, compressed the cold air and coal gas to three atmos-

pheres before entrance into the cylinder. By this a greater expansion and transformation of heat is possible."

This opinion became common at this time. Compression engines were proposed with great clearness and a full understanding of the advantages to be gained.

In 1862 Beau de Rochas first proposed the cycle now generally known as the Otto cycle, composed of four single strokes, viz:

1. Suction during an entire outstroke.
2. Compression during instroke.
3. Ignition at dead point and expanding during next outstroke.
4. Exhaust of burnt gases during next instroke.

He also proposed to supplant all igniting devices by obtaining spontaneous ignition from a compression of the charge to one-fourth of original volume (318.2 degrees Fahrenheit).

In 1867 Otto and Langen constructed a free-piston engine on the same lines as Barsanti and Mateucci, but which, by reason of better working out of mechanical details, became a commercial success.

The first practical benzine, or naphtha, engine was built by Hock in Vienna in 1870; and in 1872 Brayton, in Exeter, N. H., built the first engine using ordinary lamp petroleum of 0.85 gravity, which was also the first oil engine using combustion at constant pressure, but only six per cent. of the heat was utilized.

In 1876 the Otto silent engine, with the first practical application of the Beau de Rochas cycle and compression before explosion, was brought out and soon dominated the field. Since then improvements have been in matters of detail only, and after the expiration of the Otto master patent this type was adopted by all builders of gas or oil engines.

The names best known in connection with these improvements are Crossley, Atkinson, Hornsby, Tangye, Priestman, Capitaine and Clerk.

The heat efficiency as measured in brake horse power has slowly risen from the 6 per cent. of Brayton in 1873 to 14½ in 1888, about

18 in 1890, 21.25 per cent. in 1894, to the highest result obtained on a 100-H.P. Otto gas engine by Prof. Spangler in 1895, viz: 23½ per cent. Much confusion is created by quoting efficiency as referred to I.H.P. This is the usual and convenient method employed for steam engines, where the total friction losses are generally conceded to range between ten and thirteen per cent. In the case of gas and oil engines the limits are not so well defined, and generally range higher, say between 16 and 25 per cent., and in some cases even more. The only rational way, therefore, in comparing motors of such great variation in type is to refer all efficiency to the brake H.P. Another thing must be considered in comparing a steam engine with a gas engine. It would not be fair to the former to refer the efficiency of the gas engine to the heat units present in the gas. Just as the steam engine is charged with the loss in its necessary adjuncts, boiler and furnace, so the gas engine should be referred back to the actual coal, thus covering the losses in the gas producing plant. This shows the best present gas engine economy from coal to range between 17 and 19 per cent., the higher results being only reached with large engines and with all conditions very favorable. The best builders will not guarantee higher than 17 per cent. from coal. For oil engines the best results are about as follows:

Name.	Year.	Pounds per B.H.P. per hour.	Actual efficiency per B.H.P.
Priestman	1891	0.84	0.15
Hornsby	1894	0 97	0.14
Trusty	1894	0 82	0.16
Crossley-Otto	1894	0.82	0.16
Deutz Otto	...	0.96	0.15
Grob-Capitaine	1894	0 59	0.21

The last result is again a solitary result high above the average of good engines of this type, and in this case the fuel value of the oil is reported as rather low, both facts giving color to the suspicion of an error somewhere in the report. We may conclude, then, that the highest results attainable for the three types of engines in average good practice are twelve per cent.

for the steam engine, sixteen per cent. for the oil engine and eighteen per cent. for the gas engine, all figured from the actual heat value of the coal or oil to the effective or break H.P.

By this measure, then, gas and oil engines have fulfilled the predictions of some of our engineering prophets. In 1854 Rankine expressed the belief that: "Air engines will be found the most economical means of developing motive power by the agency of heat." Ericsson, fully in accord with him, about that time invented his caloric engine, but was able to get only 2 pounds pressure in his cylinder, the defective method of heating the air being responsible for his failure. Somewhat later, Prof. Fleeming Jenkin, speaking to a society of British engineers, said:

"Since that is the case now, and since theory shows that it is possible to increase the efficiency of the actual gas engine two or even threefold, then the conclusion seems irresistible, that gas engines will ultimately supplant the steam engine. The steam engine has been improved nearly as far as possible, but the internal-combustion gas engine can undoubtedly be greatly improved, and must command a brilliant future. I feel it a very great privilege to have been allowed to say this to you, and I say it with the strongest personal conviction."

Within the last decade the increase in the number of gas and oil engines sold has been remarkable, and there are now upwards of a hundred firms in Europe and America engaged in their manufacture. Gas engines are built up to 400 H.P. each, and oil engines up to about 100 H. P. The highest pressures used are about the same as in the latest improved triple expansion steam engines. But the dangers and breakages incident to parts overheated for the purpose of ignition, the repetition of shocks due to the explosions, making excessively heavy working parts necessary, the large fly-wheel required for the four-stroke cycle, and the difficulty of governing, have combined to prevent building of such large units as are usual in steam engine practice.

It seems that a still greater step forward in economy must be made before that which the prophets have foretold—the gradual supplanting of the steam engine by the hot-air motor—can take

place. This step has now been taken by Rudolph Diesel, a brilliant young engineer of Munich, Germany. It has been taken after a most conscientious and exhaustive study of the problems to which he devoted fifteen years of his life. For a better understanding of the steps by which he reached his success, a short statement of the difficulties and methods of previous practice will be of advantage.

While it is usual and proper to distinguish between gas and oil engines, we may group them together for this purpose, since before the oil is brought to combustion or explosion, it is first vaporized and this vapor mixed with air to form an inflammable charge, just as in the case of the gas engine. We have—

1. Engines igniting at constant volume, but without previous compression.

2. Engines igniting at constant pressure, with previous compression.

3. Engines igniting at constant volume, with previous compression.

In the first there is really a sub-type, the free piston engine, in which the sudden and unchecked expansion goes to below atmospheric pressure and creates a vacuum for the back stroke; but this type is now obsolete. All now use the de Rochas or Otto cycle, with but slight modifications. The first type has the disadvantage that at most 60 to 100 pounds initial pressure can be obtained, that the slightest throttling in suction or exhaust is ruinous to economy, and that very long strokes are necessary to obtain sufficient expansion.

The second type has the disadvantage that the conditions of its success are that there should be no heat gained and no throttling while charging and no throttling or heat lost while entering the motor cylinder, no back pressure during exhaust and no clearance in the motor cylinder—all conditions impracticable to realize.

The third type is the one which has persisted. But its difficulties are mainly the questions of governing, of ignition and of clearance. The clearance space in such an engine is necessarily large, because igniting devices must be introduced

therein, and the combustion chamber must be apart from the working section of the cylinder, for the great heat herein generated makes lubrication impossible. This clearance sometimes runs as high as thirty per cent., leaving only seventy per cent. of the total volume for the working cylinder. The objection to this clearance in reducing the effect of the expansion is the same as in the steam engine. While there is nothing akin to cylinder condensation to be increased by this clearance space, there is another serious objection to it in its containing a volume of spent gases at the end of the instroke, which will dilute the entering charge and render its exact composition doubtful.

The ingenious method of Atkinson, called scavenging, by which the first in-rush of fresh air is made to sweep out this spent gas, is partly successful, and other devices, with varying degrees of success, have been employed without, however, eliminating the difficulty. Compression before explosion is now generally recognized as a great advantage. It makes greater initial pressure from explosion possible; it makes the charge more easily inflammable and it adds heat, and both assist the ignition device which may be used. In some cases a special ignition tube has been discarded, it being found that with these effects of compression the walls of the combustion chamber or the vaporizer were in themselves sufficiently hot to ignite the charge.

This great clearance does harm in another way. For every kind of oil vapor or gas there is a certain best mixture, *i. e.*, the one which will give the highest pressure of explosion. Now, as the amount of clearance space fixes the total volume of the charge at the dead point, it naturally exactly limits the amount of fuel which should be mixed with the air, and this increases the difficulties of governing. In the vast majority of engines, governing is done in the "hit-and-miss" way, *i. e.*, by injecting a full charge of fuel at normal speed, or less than speed, and cutting off the supply entirely when the speed is too great. This makes it impossible to avoid irregularities in speed. Other methods, such as holding open the exhaust valve longer, so as to reduce the entire volume of air in the cylinder, of

course reduces the amount of previous compression, and hence the amount of initial pressure and the effect of expansion.

All igniting devices have their objections. The electric spark often fails to ignite; the direct flame is so uncertain and objectionable that it has been discarded. The hot tube is apt to wear out or even burst, and the red hot end to a cylinder is inconvenient and necessarily short lived. Otto and Capitaine both claim great advantages from stratification of the charge, so that the igniting device would act on the more inflammable portion and the speed of the explosive action be somewhat slowed down. This stratification is strongly attacked by Clerk and others. It is probably just as hard to stratify as to thoroughly mix the charge in the short time available in an engine making 200 revolutions per minute, and the fact that unburned gas and petroleum vapor escape from the exhaust pipe, and that valves and casings, and sometimes even the working cylinder, have to be freed, from time to time, from precipitated carbon, shows that the mixture of air and fuel is seldom complete. The amount of clearance might be reduced if the compression of the charge could be carried further. De Rochas did suggest compressing to the igniting point; but in practice this is not feasible, because a slight difference in the richness or temperature of the charge or in the quality of the fuel might induce premature explosion, stopping or possibly even destroying the engine.

Another drawback incident to large clearance and the necessity of exact proportions between the fuel and air is that the consumption per H.P. grows rapidly, much more so than in the case of the steam engine when the load is reduced. The highest efficiencies reported are only possible when the engine is working at its rated capacity under a constant load. For most of the uses to which motors are applied in practice variable loads do occur. And the practical value of a motor, therefore, depends not on its results in a test whose conditions have been carefully prearranged, but on its economy under working conditions through a longer period.

All internal combustion motors, however carefully designed, have the one defect in common that once the charge is ignited the

combustion or explosion is beyond control whether as to temperature or pressure.

This was, then, the condition of the problem as Diesel found it. His invention consists first in carrying compression to its rational highest limit by compressing the air separately from the fuel, and hence to a pressure and temperature far above the igniting point of the fuel used. While others are limited as to the amount of air they may admit, he not only uses but utilizes a complete cylinder volume of air. He then injects the oil or gas at a slightly higher pressure; he introduces it just at the point desired and continues its introduction during either a predetermined or a variable portion of the stroke; and his great advantage is in absolute control of the temperature, pressure and duration of combustion. As he is enabled to carry an entire cylinder full of air, he has an excess of oxygen present and his combustion is perfect and complete. Requiring no igniting device, as every charge ignites spontaneously, the hottest portion of the cylinder, the small clearance space used as a combustion chamber, can be kept cool, instead of requiring to be extremely hot. There is no shock of explosion, but the compression rises on an adiabatic curve to practically the highest point, and combustion proceeds with no increase of temperature or a relatively small one, the added heat being immediately transmuted into work down to the point of cut-off, whence adiabatic expansion is carried as far as is consistent with rapid and certain exhaust.

We have, therefore, in the Diesel motor all points which previous inventors and investigators have longed for, the compression of de Rochas, of Schmidt and of Clerk, the slow combustion of Lenoir and of Otto, and the practically complete discharge of the spent gases of Crossley and Atkinson, the excess of air being large and the clearance small. Besides this, we have the material reduction of the temperature of combustion as compared to other internal combustion motors.

In 1893, Diesel published a pamphlet, translated into English in the same year by Mr. Bryan Donkin, entitled "The Theory and Construction of a Rational Heat Motor to Replace Steam Engines and Internal Combustion Motors." The criti-

cism of this book by German engineers and professors was so favorable that the large corporations of the Augsburg Machine Works and Friedrich Krupp, in Essen, united in offering Mr. Diesel means, facilities and men to work out his theory in practice.

In consequence, the first 12 H.P. motor was completed in Augsburg in 1894, and experiments, tests, and changes were made on the same in the sacredly guarded precincts of a special testing room, the results of which were carefully tabulated and discussed by Mr. Diesel and a well selected corps of practical experts. As the result of all this, a second motor, of 20 I.H.P., was planned and built and placed on the foundations of the first one, in October, 1896. This has since been running almost constantly ten hours each day. On April 27 and 28, 1897, Mr. Diesel published his results by lecture and practical demonstration in the presence of a large circle of mechanical experts, both at Augsburg and at Munich, Professor Schroeter, of the Technical College of Munich, assisting him by a brilliant exposition of the theories involved. Prof. Alfred Musil, of the Technical College of Brunn, Germany, who was present, writes as follows:

"These two days will, without doubt, become red letter days in the history of our modern machine building, for the success which Diesel has so far achieved with his motor is already so brilliant, the fuel consumption during the perfect working of the machine is so small in comparison to all other heat motors, that, in spite of all former opposing prophecies, the Diesel motor is not only, in full justice, entitled to the name of a 'rational heat motor,' but may be fitly called the 'source of power for the future.' The inventor is entitled to the unreserved acknowledgement and gratitude of his contemporaries."

On June 16, 1897, Mr. Diesel delivered an address fully explaining the construction, the working and economy of his motor before a convention of engineering societies of Germany at Kassel. He was followed by Prof. Schroeter in an essay developing the theory of the motor. Both papers were received with the greatest applause, and engineers who had been sent there to carp and criticise came back as apostles for Diesel's

ideas. Mr. Diesel ended by inviting all interested in the subject to visit the works at Augsburg and make their own tests and examinations. This invitation was accepted by many engineers from Germany, England, France, Belgium, Austria and Italy, and even Russia.

It was my privilege to meet Mr. Diesel and visit with him the works at Augsburg, where this first successful motor is running, during the latter half of September, and to confer with him later in Munich, Nuernberg and Frankfort in company with a number of the leading men interested in machine building in Germany. No question regarding his motor which doubt could suggest or ingenuity devise remained unanswered. It seemed impossible to bring up any problem which had not previously occurred to him or his assistants and had been worked out in every detail to a final solution. At Augsburg I was allowed to choose my own assistant and adviser, which I did in the person of an eminent practical engineer of Nuernberg, Mr. G. Marx, chief engineer of a rival establishment. I was permitted to choose my own time, and then the motor, the instruments, the fuel supply, were turned over to me, and a force of intelligent engineers and machinists were instructed to obey no orders but mine.

I saw the motor at work on September 27th, 28th, 29th and 30th. In the course of my investigations during these four days I took frequent occasion to question the erecting engineer, Mr. Schmucker, about various points, the answers to which would involve the question of the time it had been in operation, and the continuity of its service. It was completed in October, 1896, and many changes and alterations were made during the next three months, but its operation has been practically continuous for ten hours a day since the first of February. During these past eight months a number of people have been in to see it in operation, have had it taken apart and put together again for their inspection. Judging from what I saw during the time I was at the works, there has been no time to do any special cleaning, or any repairs except those of a very trivial nature.

Official tests were run on the 1st, 4th, 12th and 17th of Febru-

ary, on the 17th of March, on the 30th of April, and on the 1st of May. On the 30th of September, Chief Engineer G. Marx, of Nuernberg, and I ran a short test with Messrs. Reichenbach and Boettcher. I have compared these tests with copies handed me by Mr. Diesel, and certified to their correctness, except in the case of those which have been published over the signatures of the engineers who made them. These tests all point one way. They vary just sufficiently to show the independent work of the various observers and the differing conditions under which they were made. Some find better thermic and some better mechanical results than others. In general, the later results are better than the earlier ones. The consumption of petroleum per effective (or brake) horse power, when running at or near full power, varies from 215 and 218 grammes per hour, as found in some tests by the Augsburg people, to as high as 242 grammes, as found by the French engineers on May 1st, 1897. Mr. Marx and I found a consumption of only 223 grammes per effective horse power hour. The commercial or final economy of the machine when running at or near its rating, varies from about 25 per cent. to nearly 29 per cent.

In general the larger and better results are the later ones, showing that instead of losing by wear and tear, as some engineers had predicted, it is increasing in efficiency, as most steam engines do after they get down to their bearings. The consumption of oil for cylinder lubrication is only one-third liter in ten hours, considerably less than one-tenth of a gallon. This small consumption is due to the fact that the lubricant is introduced around the sides of the cylinder at a point level with the lowest position of the upper packing ring. The oil remains on the surface entirely, and that large amount which in a steam engine, where it is introduced through the steam pipe, is lost with the exhaust, is, of course, saved in the Diesel motor. Just above the bore of the cylinder there is a recess or counterbore, which forms the combustion chamber. I felt this carefully and am satisfied that only a trifling amount, if any, of the oil used for lubrication, rises into and is burnt in this chamber.

We had a number of indicator cards taken, both from the air cylinder and the air pump, and they correspond very closely to the later series published in Diesel's paper. We had several taken with one hundred diagrams on one card and others with ten diagrams on one card, and they varied only by the wear of the pencil. Those taken while decreasing the load are very interesting, as illustrating why the economy at reduced load is nearly as great as at rating.

In starting the motor after it has been stopped, two successive charges of compressed air are admitted from the air vessel, and after this the valve mechanism is thrown into gear and the regular work of combustion commences. Two charges are always used when showing the machine to visitors, as the start is thus accomplished more smoothly; but, when experimenting for themselves, the engineers frequently start the motor with a single charge of compressed air from the reservoir. As the air-pump at all times keeps this air vessel fully charged with compressed air about two atmospheres higher in tension than that on hand in the cylinder, there is always an ample supply for starting on hand after the motor has been stopped. A well fitting valve or cock near this air chamber is closed during any long period of stoppage, so that the leakage from this reservoir can be but trifling. The pressure gauge showed no diminution of pressure during such intermissions. In case the motor is run with gas instead of petroleum, the air pump, instead of compressing air, compresses this fuel gas, so that in that case a supply of compressed gas is always available.

The amount of petroleum injected at each charge is regulated by the governor, which acts on the valve by moving a long, thin wedge under a spring-guarded plunger, which moves with the petroleum pump. The prompt and efficient action of this governor was apparent when the weights on the pan of the Prony brake were removed or replaced successively.

The air pump and the main cylinder, as well as the valve chambers, which are placed in the cylinder head, are cooled by water jackets, and the water discharged from the same is between 13 and 15 liters per minute, or about 4 gallons, and its tem-

perature about 35 degrees centigrade, or less than 100 degrees Fahrenheit. This is only about one-sixth of the amount of water used by a condensing steam engine.

I examined the interior of the cylinder, the suction and exhaust and petroleum valves twice, once on September 28th and once on the 30th, and in each case within 15 minutes after stopping. There was practically no evidence of wear. I put my arm through the valve opening as soon as the valve was removed, and found the temperature of the metal rather less than that in the cylinder or valve chamber of a steam engine under similar circumstances.

The arrangement for injecting the petroleum is cleverly devised for distributing it in a spray very thoroughly throughout the combustion chamber. I examined the valve and the nozzle very carefully in each case and found them perfectly clear. Whether they would work as well, as they are, with Lima oil or fuel oil, experiment only can determine, but as the oil will always be hot before it reaches the nozzle, it will be in its most fluid state, and I anticipate no difficulty in blowing it in, through the small holes, with the two atmospheres of surplus pressure always available from the air chamber. Should this not be sufficient, the modifications to make it work perfectly on this fuel would soon be determined by experiment. While, of course, the erecting engineer and his assistants were always available, they had nothing to do except occasionally to refill an oil cup, or manipulate the motor as desired by visiting engineers. When left to itself the motor ran with perfect precision and regularity. The guides and cross-head pin were perfectly cool, the crank and main bearings were cooled by a current of water running through them, although even this seemed hardly necessary.

When at work the motor is practically noiseless. The oiling of the moving parts is well managed by good self-feeding oil cups and a series of small pipes, as is now the practice with good steam engines. Probably there was a little more oil used than would be necessary for ordinary practice, in the desire to put the motor through its best gaits before its many critical visitors.

Both at Augsburg and at Nuernberg they are putting the

Works on about six of these twenty H.P. motors, so that within a few weeks each factory will have two perfect motors on exhibit. It is their intention then to have one motor running at all times, driving a part of the shafting of the works, and another one standing ready for experiments or examination by visitors. Everything done during my presence was plainly open and above board, and there was no attempt at concealment of anything whatever.

There have been a number of tests of the motor by experts from Germany, France and Switzerland. I give the principal results of these tests in tabular form below. What we are most concerned with is, of course, the commercial or final efficiency, *i. e.*, the percentage in mechanical work the motor will develop from a given amount of potential heat energy in the fuel. The motor is rated at twenty H.P. on the metric standard. Ordinarily we class engines according to their indicated horse power, which is generally from ten to fourteen per cent. greater than the brake H.P., the difference being absorbed by the machine itself. This motor, when run at its rating, indicates about twenty-five H.P. on the average. The losses in the engine are somewhat greater than in a good steam engine, but its effective or brake H.P. is about the same as that of a good steam engine of twenty H.P. The table below shows the principal results of six tests made by different observers. These tests were run by Mr. Dyckhoff and Mr. Diesel for the French company which has since been organized under the name of the French Diesel Motor Co.; by Messrs. Stein and Diesel for the Deutz Gas Motor Co.; by Messrs. Sulzer and Diesel for the Sulzer Bros., of Winterthur, Switzerland; by Professors Schroeter, Brueckner and Munckart, of the Munich Polytechnic School; by Messrs. Carie, Merceron and Sauvage, of Paris, for the French Diesel Motor Co., and by Chief Engineer Marx and myself for the American interest.

I am so well satisfied of the care and exactness with which the previous tests were run, that I contented myself with a short test, merely to corroborate the others. A short test, taken right out of the regular run of the engine, is perfectly satisfactory, because the instruments are all accurate and well calibrated, and the amount

of petroleum expended can be weighed with great precision. A number of short tests have been run by the two young engineers in charge, the results of which are even better than those quoted. There are two cans of coal oil placed on a shelf in full view, each provided with a funnel, into which the overflow from the petroleum pump runs in plain sight. It first drops into a square pan having a division in the middle. By simply shifting this pan on a slide under the drip pipe, the overflow can be directed into the first or second can at will. The cans are again connected to the suction pipe of the petroleum pump by pipes supplied with tight-fitting valves and unions. At the word of command the little pan is shifted, one cock closed and the other opened. I took the additional precaution to disconnect the pipe from the pan not in use by breaking the union joint, thus satisfying myself that the cock by which we had shut it off was perfectly tight. Just before closing the test the union joint was again made, and at the exact second the cocks were reversed and the distributing pan shifted. The error could thus be reduced to a few drops of petroleum. I then personally adjusted the small petroleum scale and weighed the difference, or the total oil expended, in grammes.

The weights on the pan or platform of the brake are standard government weights. The pan itself, with chains and equalizing weights, was then disconnected and also weighed by me in person. Mr. Marx, in my presence, measured the diameter of the fly wheel and the distance to tension cord. From the reports of the other tests I am sure that the same precautions were observed by the other engineers. In the table below I give at the head of each column the name of one observer in each case by which the test can be located by reference to the schedule above given. The horizontal lines are numbered: 1 gives the date, 2 the number of revolutions per minute, 3 the indicated H.P., 4 the effective H.P., 5 the number of grammes of petroleum per hour for each effective H.P., and 6 the final or commercial efficiency in per cent.

All other data I shall be glad to furnish by reference to copies of the tests themselves which I have on file.

RESULTS OF ECONOMY TESTS.

	Dyckhoff.	Deutz.	Sulzer.	Schroeter.	Carie.	Marx.
1.....	Feb. 1,'97	Feb. 4,'97	Feb.12,'97	Feb.17,'97	Apr.30,'97	Sept. 30,'97
2.....	163	152	161.4	154	165	166.2
3.....	24.10	23.15	25.4	24.7	26.7	26 6
4.....	18 84	17.50	18.61	17.8	19.1	19.2
5.....	234 grs.	238 grs.	242 grs.	238 grs.	242 grs.	223 grs.
6.....	26 pr. ct.	26.2 pr. ct.	26.6 pr. ct.	26.2 pr. ct.	25 6 pr. ct.	28.6 pr. ct.

There were a number of tests run by the various observers on the motor running at or about half its regular load, and even less, with a view to determining its economy under such conditions. It is well known that a steam engine running at considerably less than its normal or rated load loses very much of its economy. This is evidently not the case with the Diesel motor. The lowest percentage of commercial efficiency found under such circumstances was 21.5, and various observers found it from this up to 24.1 per cent. An average of all results gives about 23 per cent. at half load.

I have preserved a number of indicator cards made during our tests, which have been run over by planimeter both by Mr. Marx and Mr. Boettcher. As these diagrams are necessarily very small, there is a little difference between the two observers, as would naturally be expected. The indicator used is a very nice and delicate instrument, made by Messrs. Schaeffer and Budenberg. For use with ordinary steam engines it has the regular size piston. For use on the Diesel motor it has a reduced piston of an area just one-quarter of the other. We must remember that our diagrams run up to 35 atmospheres. This will account for the slight difference in the calculations of the cards. In estimating the H.P. from these cards we must remember that only each fourth stroke is a working stroke, this being a four beat machine.

The motor is running ten hours daily at its original location in Augsburg, except when interrupted by delegations of visiting engineers and manufacturers for thorough internal inspection. Thus far, neither the inventor nor the manufacturers claim any

practical results on any other fuel than petroleum. This in itself is evidence of the value they place on the invention and the integrity and care of their statement. They will make no statements except positive ones, and for those they require a whole series of experiments, managed with great care and thoroughness. Besides ordinary petroleum they have, however, been making interesting laboratory experiments on different kinds of natural oils, residual products of Russian petroleum, American gas oil, illuminating gas, producer gas and even coal dust. The experiments are still going on, although naturally interrupted by the visiting delegations before mentioned.

A second motor of the same type and size is nearly completed and will be placed in the same testing room, so that the practical tests on these various fuels can be made without danger of interruption, the first motor to be then used as an exhibit.

Another motor, having three cylinders and arranged for compound compression and compound expansion, is completed and now in its experimental state. This is to run at 125 to 150 H.P.

The interest created by this invention in Europe can only be likened to that occasioned in this country by the successful introduction of electrical light and power. Some of the largest and most important works have taken out licenses and are actually building motors of various types. The following is a partial list:

Augsburg Machine Works; Nuernberg Machine Works; Deutz Gas Motor Works; Sulzer Bros., Winterthur, Switzerland; Friedrich Krupp, Essen; Friedrich Krupp, Magdeburg-Buckau; The Mirrlees Watson & Yaryan Co., Glasgow; Société Anonyme des Moteurs Diesel, Bar-le-Duc; Carels Feres, Ghent; Burmeister & Wains Machine and Shipbuilding Works, Copenhagen; Titan Machine Works, Copenhagen; Diesel Motor Co., Augsburg; H. Pauksch Machine Works, Landsberg.

An American company with large capital will be formed for the introduction of the Diesel motor during this month, and before the end of February a motor will be on exhibit and offered for tests in New York City.

While these first motors are only built for stationary purposes,

railway motors, street car motors and marine motors have been designed by various firms above mentioned and will probably all be completed and running during the year. A joint exposition by builders of the Diesel motor will take place in Munich in June or July, and this will comprise various types.

The Augsburg Machine Co. have begun the construction of an addition to their immense works, solely for the building of Diesel motors. The sum of $600,000 has been assigned for this purpose, and all the machinery in these works is to be driven by Diesel motors. Privy-Councillor Buz, the President and General Manager of these works, a gentleman of large experience and sound judgment, stated to me that they would immediately begin building for larger powers, and that he was convinced that he would have a Diesel motor of 800 or 1000 H.P. running at the Paris Exposition in 1900. In his opinion, the supplanting of the steam engine, for all purposes, by the Diesel motor, is a foregone conclusion, although it will be a matter of gradual development. That a motor which has none of the disadvantages of former gas and oil engines and almost all the advantages of the steam engine, and which begins its career with an economy double that of the best triple expansion steam engine and fifty per cent. higher than the most highly developed types of gas and oil engines, gives a basis for such hopes and predictions cannot be doubted.

In November, 1896, some months before the practical results had fulfilled the promises of the theory, Prof. Gustav Zeuner, the Nestor of German thermo-dynamics, wrote as follows:

"I consider the theoretical investigations of Diesel as entirely correct, and it only remains to overcome the practical objections which have been raised against them.

"It is true that this or a similar engine would simply destroy our present steam engine, with all the perfections achieved by hundreds of men of genius. It is impossible to follow this thought without feeling absolutely crushed, for who could possibly draw an adequate picture of the revolutionary changes impending."

The first step has been taken. The main difficulties have been overcome. But we need not join Zeuner in his lament for great achievements rendered useless. The steel and iron in these

magnificent engines will be reforged and recast into newer shapes. The thoughts and aspirations they embodied will live in higher forms. The intellectual ancestry he conjures up will inspire the rising generation of engineers to emulate and excel their work. And from the extreme depression of this first realization will spring an expansion as glad, as buoyant and as full of promise as that which followed the first success of Watt, Stephenson and Fulton.

DISCUSSION.

Col. D. P. Jones, Member.—In the running of this motor is there any carbon residuum?

Col. Meier.—None whatever. The combustion is perfect and complete, without smoke and without odor.

Chief Engr. John C. Kafer, U. S. N.—This paper is, in my judgment, one of the most important I have ever heard read before any society. As it is the first presentation of the subject I have seen, I am not prepared to discuss it, but I would like to ask Col. Meier if he would give the actual cost in pounds of oil per I.H.P. and per brake H.P., and also the weight of the motor per I.H.P., for these are the items which determine its commercial success.

Col. Meier.—The oil consumption per brake H.P. varied from 218 grammes to 240 grammes, *i. e.*, about one-half pint of oil, which can be bought almost anywhere in the United States for eight to nine cents per gallon. Experiments on fuel oil at two to three cents per gallon have just been successfully made, but I have not yet received the data.

Mr. J. M. Whitham, Member.—While I agree with the opinions that have been expressed as to the importance of Colonel Meier's admirable paper, I do not at all share the pessimistic views attributed to Professor Zeuner with regard to the entire displacement of the steam engine by this new motor. I need not go into the reasons at length, many of which will be obvious on consideration, but I may say that I have no fear of seeing the steam engine in the same category as the dodo during my lifetime.

SPEED AND POWER TRIALS OF A LIGHT-DRAUGHT STEAM LAUNCH.

By Charles Ward, Esq., Associate.

This boat was designed for a light-draught, commodious and economical river craft, to run on from 20 inches to 24 inches of water, and to be propelled by a screw.

The hull is of steel; is 66 feet, 6 inches long, over all; 10 feet, 6 inches beam; and 4 feet deep, amidships. It is of that type wherein the hull is extended, with a cavity, pocket or tunnel, over the screw to exclude the atmosphere. The boat is modeled on easy lines conforming to this plan. The cavity, pocket or tunnel commences just aft of midships, at the bottom of the boat (there is no keel), and rises on easy lines until it reaches the vertical center of the screw, at which point it is 31 inches above the bottom of the boat. From this point it is built straight out parallel with the bottom and 11 inches above the water line of the boat when drawing 20 inches at the stern.

Boats previously built by ourselves and others had this tunnel so arranged that after passing the vertical center of the screw it was carried down on an easy curve to the water line. It was thought that the impingement of the water from the propeller against this drooping part of the tunnel acted as a drag and retarded the progress of the boat. With a view to determine this, our tunnel was built with a straight out delivery, and was also fitted with a removable plate which made the tunnel of the usual drooping form, and caused the water from the propeller to be delivered below the water line of the boat instead of straight out as previously described.

The frames are $1\frac{1}{4}$ inches $\times$ $1\frac{1}{4}$ inches $\times$ $\frac{3}{16}$ inch in the forward and middle part of the hull, and 1 inch $\times$ 1 inch $\times$ $\frac{1}{8}$ inch where subjected to less strain. The hull is divided into five

water-tight compartments by four plate-steel, solid bulkheads extending to the top of the hull.

The plating is of soft steel, weighing $4\frac{1}{3}$ pounds per square foot, with inner and outer strakes about ten feet long. Longitudinal seams are single riveted, the ends being joined by triple-riveted butt straps; all rivets are countersunk on the outside.

A $1\frac{1}{2}$ inch $\times$ $1\frac{1}{2}$ inch $\times$ $\frac{3}{16}$ inch steel angle, flaring outward, extends entirely around the hull, surmounted by a shelf plate, cut and formed to the contour of the house and deck line. From this are carried the eighteen-inch guards and the house. The weight of the finished hull is 7,608 pounds. The house is of mahogany throughout, and consists of a pilot house and cabin 12 feet long; buffet, 3 feet 3 inches; boiler and engine room, 12 feet 9 inches; after cabin, 12 feet 9 inches; a passage, 4 feet 9 inches, with a lavatory on one side and water closet on the other, the respective widths conforming to the width of the boat. The boat is fitted with conveniences to mess and sleep ten people.

The boiler is of the Ward launch type, known as size H—1—round; has 360 square feet of heating surface, 15.5 square feet of grate, and weighs, including grates, double casing, double and hinged smoke stack and galvanized iron air casing, 4,641 pounds. In steaming condition it contains 572 pounds of water, making a total of 5,213 pounds.

The engine is special, designed for compactness, simplicity and lightness, without sacrificing utility; is $\frac{6\frac{1}{2} \text{ inches} \times 13 \text{ inches}}{8 \text{ inches}}$; has one piston valve, controlling the steam distribution to both cylinders, and is operated by Marshall gear; space occupied is 2 feet $3\frac{1}{4} \times 19$ inches $\times$ 3 feet 9 inches.

Incidentally, I may say that, in view of the high speed of this engine and the consequent stopping and starting of the piston valve from 800 to 1,100 times per minute, it was thought desirable to reduce its weight. Accordingly, an aluminum valve was made, with allowance for the difference in expansion and contraction. The result at first seemed eminently satisfactory in the

starting and running of the engine; but on stopping and starting again it was found that the valve chamber cooled so much more rapidly than the valve that the latter was immovable. An effort to start the engine only a few moments after it had been stopped from full speed resulted in wrecking the valve gear. The valve was a combined B and D, of annular form, without packing rings. Had the valve chamber been fitted with a sleeve and the valve with packing rings providing a greater range of adjustment, the aluminum valve would, I think, have been a success. The difference in weight was 15 pounds for cast iron and 6 pounds 2 ounces for aluminum.

The boat is fitted with an outboard condenser. Starting from the exhaust pipe at the skin of the boat is a composition shoe, divided by a partition. From each division of the shoe a 2-inch pipe runs aft for 18 feet to two concentric return bends, which are reduced to $1\frac{1}{2}$ inches, from which two lines of pipe return to near the starting point and unite in a common shoe connecting with the air pump. The exterior surface is 40 square feet; weight, 245 pounds. The two lines of smaller pipe were adopted to better withstand striking solid objects in the river.

The air pump is single-acting and driven by a crank on the forward end of the main engine shaft and at the same speed. The feed pump is an independent, direct-acting, duplex, 3 inches $\times$ 2 inches $\times$ 3 inches. Its exhaust is piped into the receiver of the engine and also into the condenser, with suitable change valves.

The fire room is so arranged that it may be either open or closed, and is fitted with an open or uncased fan blower eighteen inches in diameter, taking air from outside. It is driven by a direct connected engine at from 1,000 to 1,500 revolutions per minute, maintaining a plenum of from 1 inch to $1\frac{1}{4}$ inches of water. This is used only for maximum speed.

The propeller is a composition three-bladed true screw, 30 inches in diameter, 4 feet 3 inches pitch, 694 square inches disc area, 333.4 square inches projected area, 438 square inches developed area; weight, 99 pounds. It is eight feet forward of the stern. There is a single rudder immediately aft the screw, also under the boat and in the tunnel.

To recapitulate, the weights are as follows:

	Pounds.
Hull,	7,608
Boiler,	4,641
Engine,	1,100
Shaft and screw,	494
Feed pump and condenser,	375
Steam and water connections,	378
House and furnishings,	8,897
Total weight of boat,	*23,493

* Machinery, 6,988 pounds. One H.P. for 87 pounds.

	Pounds.
Water carried in boiler,	572
Fuel,	2,000
Six operators and observers,	900
Total,	*26,965

* Equal to 12.03 tons of 2,240 pounds each.

Upon completion of the boat, several preliminary trials were made to ascertain the speed of the boat, which, under the most favorable conditions, is about 13 statute miles per hour. Trials were then made to determine the effect on the boat of the two forms of stern, viz: the one where the water from the upper portion of the screw was projected against the end of the drooping pocket or tunnel, and by it directed and discharged below the water line, and the other where there was no resistance from the form of the tunnel or pocket, and where the water was projected in a direct line from the propeller, 20 inches of which was submerged, the remaining 10 inches being above the water when the boat was at rest.

Under the first condition, immediately the screw starts the air is expelled from the pocket or tunnel, and it is charged, and remains charged, with solid water, and the screw works, to all appearances, with as much efficiency and as steadily as though under the ordinary conditions. The boat, in this condition, goes ahead, or astern, perfectly, the latter almost as fast as the former, and is quite steady. There is no squatting at any speed, but the

race from the propeller is entirely unlike that which is usual. Instead of bursting up above the surface of the river, foaming and rolling, there is following the boat, for several feet, an actual depression in the water of several inches in depth, the water from the propeller being deflected downward by the form of the overhanging stern.

With the removal of this overhang formed by the inserted plate, leaving the end of the boat and the propeller open to the air, the conditions are entirely different. Upon starting the engine at *slow speeds*, the tunnel fills with solid water and the boat remains at about its normal trim, but immediately the speed is increased, even moderately, the stern drops until the tunnel is on a level with the water, carrying a tremendous swell, and the boat vibrates from stem to stern, the vibration increasing with the speed. With the tunnel open, the boat, which before backed so promptly and almost as rapidly as it went ahead, is now as obstinate as a mule, and will not budge—backwards. While going ahead there is no evidence that she is any faster.

This matter being determined, the plate was re-inserted, making the tunnel terminate at the water line, and preparations made for a series of progressive speed and power trials over the measured course, with screws of varying pitch and area.

The first progressive trial was made with a screw of less pitch and greater area than had been heretofore used. Its dimensions are: Diameter, 31 inches; pitch, 3.89 feet; disc area, 744 square inches; projected area, 543 square inches; developed area, 694 square inches; weight, 99 pounds.

The course was a statute mile of 5,280 feet, laid off by the U. S. Engineer Corps, on a straight line in pool No. 6, on the Kanawha river, opposite Charleston, for the trial of a similar boat some four years ago, the commencement and finish being marked by stakes on the river bank, ranging at a right angle to the course. One run was made with and one against the current at each rate of speed. For each speed, the engine was adjusted by the throttle valve to the desired number of revolutions, and the steam pressure maintained as nearly uniform as possible. An observer in the pilot house took the time at the start and fin-

TABLE OF RESULTS OF TRIALS WITH SCREW A.

Three-bladed screw:—diameter, 31 inches; pitch, 3.89 feet; disc area, 744 square inches; projected area, 543 square inches; developed area, 694.4 square inches; weight, 99 pounds.

Dec. 14. 1897.	Current.	Revolutions.		Time over course.	Speed per hour.	Mean speed.	Travel of screw.	Apparent slip.	Mean slip.	Horse power.	Mean H.P.	Stage of river
		Per mile.	Per minute.									
				m. s.	*miles.*	*miles.*	*miles.*	*per cent.*	*per cent.*			
Run A 1	With	1502	162.6	9·13	6.51	6.125	7.18	9.3	14.2	9.04	8.99	Pool stage, 6.3 feet; dam 6, up.
" 2	Against	1681	160.8	10·27	5.74		7.10	19.1		8.94		
Run B 1	With	1545	203.4	7·35	7.91	7.54	8.98	11.9	14.75	15.32	15.	
" 2	Against	1650	197.4	8·21	7.18		8.72	17.6		14.68		
Run C 1	With	1594	251.4	6·20	9.47	9.09	11.11	14.7	18.15	24.6	25.6	
" 2	Against	1724	250.2	6·53	8.71		11.11	21.6		26.6		
Run D 1	With	1630	300.	5·26	11.04	10.6	13.61	18.8	20.25	47.25	45.2	
" 2	Against	1745	294.	5·54	10.17		13.00	21.7		43.15		
Run E 1	With	1840	368.	5·00	12.00	11.58	16.27	26.2	23.95	108.74	102.78	
" 2	Against	1820	338.4	5·22½	11.16		14.25	21.7		96.83		

TABLE OF RESULTS OF TRIALS WITH SCREW B.

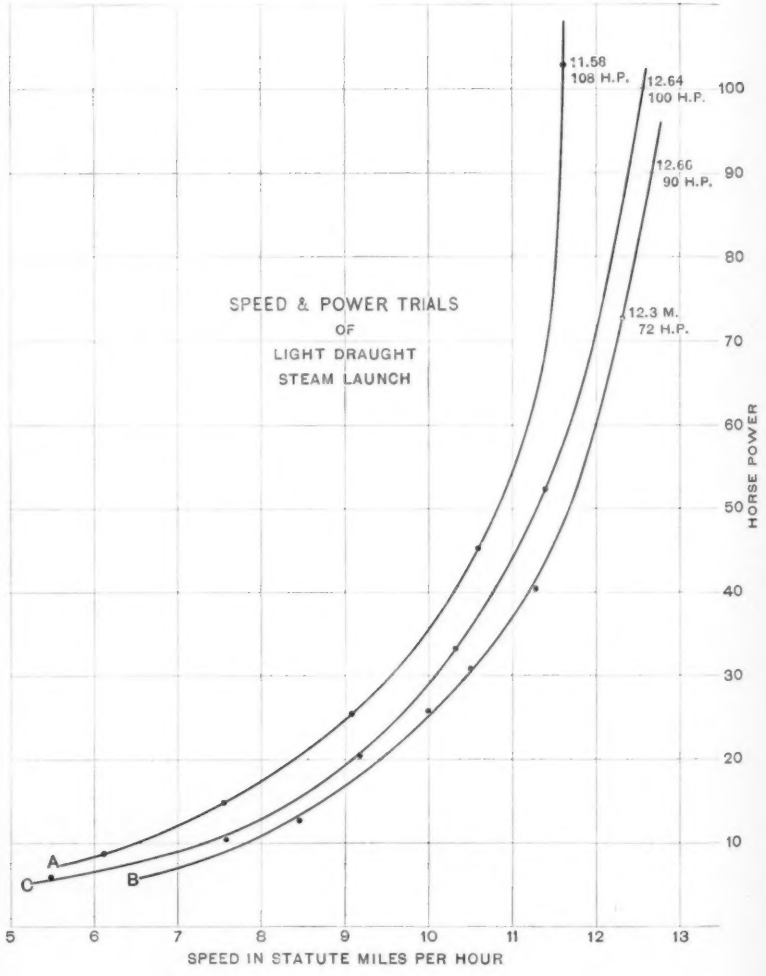
Three-bladed screw:—diameter, 30 inches; pitch, 4 feet 3 inches; disc area, 694 square inches; projected area, 333.4 square inches; developed area, 438 square inches; weight, 86 pounds.

Dec. 20, 1897.	Current.	Revolutions.		Time over course.	Speed per hour.	Mean speed.	Travel of screw.	Apparent slip.	Mean slip.	Horse power.	Mean H.P.	Stage of river.
		Per mile.	Per minute.									
				m. s.	*miles.*	*miles.*	*miles.*	*per cent.*	*per cent.*			
Run A 1	With	1,087	162	6·40	9.00	8.135	7.82	—13	—8 1	8.51	8.88	Pool stage, 7.5 feet; dam 6, up.
" 2	Against	1,376	156	8·15	7.27		7.53	3·4		9.25		
Run B 1	With	1,282	197	6·30	9 23	8.445	9.51	2.9	16.	12.53	13.54	
" 2	Against	1,758	224	7·50	7.66		10.81	29.1		14.56		
Run C 1	With	1,670	303	5·34	10.77	10.	14.63	26.4	31.3	26.9	25.82	
" 2	Against	1,940	300	6·30	9.23		14.48	36.2		24.74		
Run D 1	With	1,682	315	5·20	11.25	10.49	15.21	26.	29.4	29.76	30.86	
" 2	Against	1,848	300	6 10	9.73		14.48	32.8		31.96		
Run E 1	With	1,710	336	5·5	11.80	11.24	16.22	27.2	32.45	35.35	40.28	
" 2	Against	2.000	355	5·37	10.68		17.14	37.7		45.21		
Run F 1	With	1,910	420	4·33	13.18	12.30	20.28	35.	37.65	83.36	72.74	
" 2	Against	2,084	396.6	5·15	11.42		19.15	40.30		62.12		

TABLE OF RESULTS OF TRIALS WITH SCREW C.

Three-bladed screw:—diameter, 30½ inches; pitch, 3 feet; disc area, 718.5 square inches; projected area, 412.5 square inches; developed area, 506 square inches; weight, 74 pounds.

Jan. 5, 1898.	Current.	Revolutions.		Time over course.	Speed per hour.	Mean speed.	Travel of screw.	Apparent slip.	Mean slip.	Horse power.	Mean H.P.	Stage of river.
		Per mile.	Per minute.									
				m. s.	*miles.*	*miles.*	*miles.*	*per cent.*	*per cent.*			
Run A 1	With	1752	194	9·2	6.64	5.93	6.61	—.43	2.7	6.17	5.48	Open stage, 3 8 feet; dam 6, down.
" 2	Against	1874	163	11·30	5.22		5.55	5.9		4.8		
Run B 1	With	1859	252	7·21	8.16	7.58	8.59	5.	11.85	10.21	10.6	
" 2	Against	2169	252.6	8·35	7.		8.61	18.7		11.		
Run C 1	With	1916	313	6·7	9.80	9.13	10.67	8.1	14.5	20.	20.31	
" 2	Against	2228	314.6	7·5	8.47		10.71	20.9		20.63		
Run D 1	With	1988	361	5·30	10.90	10.32	12.30	11.3	16.15	33.35	33.18	
" 2	Against	2230	362.4	6·9	9.75		12.35	21.0		33.01		
Run E 1	With	2107	421	5·00	12.	11.38	14 35	16 4	21.	52.27	52.35	
" 2	Against	2368	425	5·34	10.77		14.48	25.6		52.43		
Run F 1	With	2318	512	4·31½	13.26	12.64	17.45	24.	27.85	Lost.	.....	
" 2	Against	2580	516	5·00	12.		17.59	31.7		Lost.		


SPEED & POWER TRIALS
OF
LIGHT DRAUGHT
STEAM LAUNCH
11.58
108 H.P.
12.64
100 H.P.
12.60
90 H.P.
12.3 M.
72 H.P.
A
B
C
HORSE POWER
100
90
80
70
60
50
40
30
20
10
5
6
7
8
9
10
11
12
13
SPEED IN STATUTE MILES PER HOUR

ish with a stop watch, and at the same moment, by a single stroke bell, signaled an observer in the engine room, who took and recorded the revolutions of the engine. Five double runs were made at varying speeds; during each run indicator cards were taken from the high and low pressure cylinders; from these and the revolutions the horse power was calculated. The indicators were carefully standardized, and the corrections made accordingly.

The results of the first progressive trials are given in Table A.

Trials were then made as before, with the results as tabulated in Table B.

The slip was uniformly so excessive that it was decided to substitute a three-bladed wheel, 30½ inches in diameter, 3-foot pitch, 718.5 square inches disc area, 412.5 square inches projected area, 506 square inches developed area; weight, 74 pounds, and run another trial, particulars of which are given in Table C.

The simple data are given so that each may draw his own conclusion. The trials have been conducted with all the care that the conditions permitted. There is doubtless some error, chiefly attributable to the small quantity of water in the river, the difficulty of running the boat in an absolutely straight line, its course being disturbed more or less by the varying currents and depth of water, the contiguity of the river banks, and the wind. Nevertheless, they are, I believe, as accurate as these things usually are. This is shown by the uniformity with which the curve and power lines cut the several stations, shown by diagram of curves herewith.

It will be seen that screw *B* having the greatest pitch and the least surface gives the most speed with the least H.P.

I have given my attention to this particular style of boat, hoping it might open the way to an improved class of steamers for our wonderful, beautiful and useful rivers—arteries of commerce far in excess of those of our ocean ports.

It is a fact, much to be regretted, that there has been comparatively little improvement in our river steamers during the past twenty-five years. They are still propelled by the same old, simple, long-stroke engines, using steam at from 150 to 200

pounds, cut off at from five-eighths to seven-eighths of the stroke and exhausting steam into the atmosphere, with as much useful work in it at the time it leaves the cylinder as that utilized.

A few years ago we furnished boilers for a Western river tow-boat. The engines were two twenty-inch diameter, eight-foot stroke, 225 pounds steam, following three-fourths stroke. I have indicator diagrams taken from these engines, showing that the steam exhausted at 150 pounds above the atmosphere. These engines run at from twelve to twenty revolutions per minute, and the weight is consequently very great per H.P. It is hardly practicable to use triple or quadruple engines in connection with stern paddle-wheels; but if propellers can be used on these shallow draughts, we can then use high speed and high expansion engines with exceedingly reduced weight and greatly increased economy.

Mr. Thornycroft has, perhaps, been most active in development of this class of boat, in connection with his turbine propeller. Those who are interested will find his most excellent article in the magnificent marine number of "Cassier's" magazine, most instructive.

The most important structures on this principle are, perhaps, the light-draught gunboats recently built for the Egyptian government, of 140 tons displacement on two feet draught, by Mr. Thornycroft and by Mr. Yarrow. In the boat built by Mr. Thornycroft his turbine propellers, three feet six inches diameter, are used with an immersion of only two feet; but in the boat built by Mr. Yarrow we have the novel condition of screws four feet six inches diameter with less than two feet immersed when the boat is at rest.

It would add greatly to our information if the builders or the Admiralty would publish the data of the trials of these boats. In the published account in "Engineering" there is great disparity in the horse powers; that for the Thornycroft boat is 426, while that of the Yarrow boat is stated as 600. The boats are identical.

Can it be possible that this difference in horse power is accounted for by the advantages of the guide blade propeller? Or is it due to the difference in immersion? Or is it an error?

NOTES.

COMPRESSED AIR EXPLOSIONS.

[By Frank Richards. Reprinted from the "American Machinist."]

The fact that steam boilers explode is not, in these days, cited as a reason for abandoning the use of steam, and the fact that explosions have occurred in connection with the use of compressed air does not constitute it a legitimate weapon for the alarmist, or furnish any reason for avoiding the employment of compressed air for the uses to which it is specially adapted. There is and there can be no means of power transmission that can not be made dangerous. If force can be applied it can also be misapplied. The use of compressed air in considerable volumes and under high pressures, is quite recent, and at the beginning there has been naturally a time of more or less ignorance, in which some dangerous conditions have been permitted to occur, and in which and by which valuable experience has been accumulated. In the case of compressed air, this period has been a much shorter one than in the case of steam, for instance. We have progressed, even now, far enough to make it proper to say and to maintain that the conditions, under which explosions of compressed air mixed with oil vapors occur, are so well known that those who to-day permit them to exist must be more or less liable to the reproach of not knowing what they might and what they should know, or to the charge of not appreciating or of not fulfilling their responsibility in the matter.

As with the freezing up of compressed air, or rather with the choking up of the exhaust passages by accumulations of ice, which involves the concurrence of two distinct conditions, the sufficiently low temperature and the presence of moisture in the air, so explosive mixtures can only be formed and explosions of them can only occur where there are at once the two conditions of high

temperature and of vaporized oil in sufficient quantity, or of oil that may be volatilized by and mixed with the heated air. These conditions of danger being understood, it should be a simple thing to prevent their simultaneous presence.

It must be acknowledged that there is here in some cases a temptation to run a risk. Economy of power in air compression requires that the compression be done by stages, with efficient intercooling, and in this way high and dangerous temperatures are avoided. A single stage compressor is simpler and cheaper, and, especially for temporary plants, may seem to be preferable, and when adopted it may involve, especially when recklessly run, the danger of excessive temperature and of oil suspended in the heated air and consequent explosions, and, as I have said before, the typical cases of explosion have been chiefly of this character, but where they have been permitted to occur, or where they should now be permitted to occur, someone has been or would be to blame.

Even in cases of single stage compression up to seven or eight atmospheres, where the temperatures reached by the air are high enough to cause ignition, the danger is largely contingent upon the manner in which the lubricating oil is fed to the cylinder. If the oil is fed continuously drop by drop the danger is not so great as when the same total quantity is fed intermittently. In the first case the lubricating effect will be better, and the volatile portion of the oil will mix with the air and be carried along without at any time forming a mixture sufficiently rich to be explosive. But if the oil is dumped into the cylinder by the teacupful, or something like that, as in aggravated cases it sometimes is, all the necessary conditions would seem to be present, and it should not be wondered at if an interesting explosion should occur, and then some one or something other than compressed air in general should be blamed for it.

In single stage compressors working to seven or eight atmospheres, and where the temperature of the air as it passes out of the compressing cylinder will exceed 400 degrees Fahrenheit, there will be, with either style of feeding the oil, an accumulation of residuum in the passages which in time must materially reduce

their area. It is wise, therefore, to make all such passages large, and also necessary at times to clear out the obstruction.

The article which the "American Machinist" reproduced from "Glückauf" would be worthy of more consideration if the compresser employed in the experiments narrated had been more correctly designed. The long and extremely small air passages for the discharged air were an absurdity, and by their rapid choking up introduced another element of danger, which could have been easily avoided. The additional heating up of the air by its friction when already so hot was a needless exasperation.

I have spoken thus far of the dangers which the ill-designed or the ill-managed compresser may invite, and, as a matter of fact, most of the explosions which have occurred have been, as far as I know, at or near the compressor, and have been caused somewhat in the way that I have indicated. The contribution of Mr. Wm. E. Gibbs in the "American Machinist" of January 13 tells of an extremely forcible explosion with which the compressor had nothing to do, yet which resulted from the same conditions of very hot air, in this case also at very high pressure, and plenty of oil. There was a long, depressed run of pipe, filled with air, presumably at normal pressure and temperature, and there was a lot of oil, which had accumulated there on account of the dip. Air at 1,700 pounds was suddenly turned on to this pipe, the inclosed air was compressed and intensely heated, the oil was vaporized and mixed with the air and exploded with such force as to burst the pipe, which had been tested to a pressure of 6,000 pounds to the square inch. This trick might be played with compressed air in many cases, if the possibility of it was not guarded against, and if the possibility had not been thought of. Probably by some engineers it has not even yet been independently thought out, so that the publication of the incident is a public service.

It is probably very certain that a similar incident could not occur again in any compressed-air plant that might be in charge of Mr. Gibbs. So in the installation of a compressed-air plant upon a United States ship of war, the contemplation of the possibility of which suggested the present discussion, it may fairly

be assumed that there would be in those in charge sufficient knowledge to render the possibility of danger an unwarrantable suggestion.

It may be considered something of a coincidence that at this exact time, and, in fact, since the above was written, there has occurred right here in New York a typical explosion of the class which we are considering. There was first the lack (in this case certainly not culpable) of accurate knowledge as to the danger of the conditions which were permitted to occur, and then there were the conditions in detail, the compression of air to a high pressure and the consequent high temperature, the presence of sufficient oil to form an explosive mixture, and then the almost inevitable ignition and explosion, with the death of two men as a consequence. The accident did not occur in connection with the regular or legitimate use of compressed air, and no persons familiar with compressed air practice had anything to do with the matter. It was in a brewery, where it had been the custom, after overhauling or repairing the ammonia compressors, to pump up with air to a considerable pressure, to see that the joints were all tight before recharging with ammonia, and this operation was undertaken in this case. It was not supposed to be a test of the strength of the pipes or other parts, as they were amply strong. The usual working pressure for the ammonia was about 180 pounds, while the air test was carried higher than that, 300 pounds having been frequently applied. The explosion occurred at a pressure below 240 pounds. Pieces of the cast-iron pipe flew in various directions, one piece striking the engineer, who was only three or four feet away, another piece hitting another man at a distance of thirty feet or so. Both men were killed. All the windows of the engine room were blown out, and a large surface of the ceiling was blackened by the exploded charge. The still attached portions of cast-iron pipe, which was, perhaps, 5 inches in internal diameter, were about $1\frac{1}{4}$ inches thick, of good sound iron, and I have no doubt would have been safe at 1,000 pounds pressure.

The reason of the explosion is self-evident. The air was intensely hot and there was enough oil present to make an ex-

plosive charge. That an explosion had not occurred on some previous "test" was simply because the conditions had not concurred. It is to be supposed that the oil had not been present in sufficient quantity, for it is not likely that the air temperature was lacking.

Occurrences such as this demonstrate, of course, the necessity of disseminating as widely as possible the knowledge of the conditions to be avoided. They do not in the least militate against the proper use of compressed air.

[The details of the explosion reported by Mr. Gibbs are as follows (from his letter):]

A tank was about to be charged with compressed air from a large sectional reservoir, for the purpose of testing a new charging valve. The usual working pressure was something over 2,000 pounds, but since the air in the main reservoir had not been replenished for a couple of days, this had fallen by leakage and use to about 1,700 pounds per square inch.

The reservoir was in a building at a distance of about 100 yards from the laboratory in which the explosion took place, and was connected with the experimental department by means of a steel tube laid underground. At the end of this tube, within the laboratory, was a high pressure angle valve similar to an ordinary globe valve. From this valve a steel pipe descended vertically about 4 feet and thence extended along the floor for 20 feet, where it entered a fitting containing a universal joint. Thence a pipe was carried upward to the charging valve first mentioned, which was being tested. The charging valve could be moved about on the end of its pipe by reason of the universal joint. It had just come from the shop, had been attached to the end of the charging pipe, from which the air had previously been shut off by means of the angle valve, and had then been coupled to the tank which was to be charged.

It must be borne in mind that the pipe joining the two valves consisted of two short vertical pieces connected at their lower ends by a long horizontal one. These pipes I had seen tested

to a pressure of 6,000 pounds per square inch, and they had been in daily use under an air pressure of over 2,000 pounds.

Everything being ready for the test, a man was told to throw over the lever which opened the charging valve, but he, remarking that the air had not been let into the charging pipe, proceeded to open the angle valve where the main pipe entered the building. A frightful explosion occurred at the moment of opening this angle valve. It was much louder than the air explosions which I had previously heard, being sharper and more deafening in character. It was, moreover, accompanied by a great burst of flame, which, together with the concussion, left one dazed for a minute or more. Fortunately, no one was injured.

"Upon investigation I found that a portion about three feet long had been torn out of that end of the horizontal pipe nearest the universal joint. The piece, which was about an inch wide, had broken into two smaller sections, one of which had gone entirely through a two-inch spruce plank, and the other was sticking up like a sword blade from the heavy floor which it had penetrated. The universal joint was wrecked. One piece of it, a plug two inches in diameter by the same height, had gone through the floor and eight inches into the tightly packed earth below. The pipes and fragments, as well as the floor near the rupture, were coated with a fine dust-like deposit of soot. An odor of oil was noticed, but that always attends an air explosion. The effects of the explosion extended no farther. Both valves and vertical pipes were intact, as well as more than three-quarters of the horizontal portion.

Now, in my opinion, this explosion could have been caused in only one way, and that by the firing of a mixture of oil vapor or spray mixed with air. First as to the oil. While it is true that no great amount of oil comes away from a good compressor with the air, it is also true that a small portion is carried off as spray and a still smaller amount as vapor. After a time, as this oil is driven along the delivery pipes, it settles into such corners or pockets as it can find, and where a pipe drops to a lower level, from which it afterward rises, a very pretty trap is formed, as in

the case under consideration. Some of the first reservoirs with which I experimented were placed horizontally with the inlet and outlet pipes at the center of their heads. I knew that moisture would condense in the reservoirs, but thought it would evaporate when the air was withdrawn. They were, however, soon found to be half full of water, with a thin film of oil on top, which prevented evaporation most effectually.

Our compressors were as nearly perfect as such things can be, one being a three and the other a four stage machine, with plenty of cooling surface and ample supply of water thereto.

Finally, for the direct cause of the explosion. We had two closed valves connected by a loop of pipe containing oil and air at atmospheric pressure. One valve is opened, letting high pressure cool air into the space. The incoming air stirs up the oil, catches it in the narrow pipe and drives it like a plunger down the tube. The air originally contained in the pipe is compressed by the incoming air just as if it were being acted upon by a piston. Its temperature is almost instantly raised to that corresponding to a red heat, or above. The small amount of oil present is vaporized and fired as prettily as though Messrs. Hornsby & Ackroyd had superintended the performance. The man who survives the experiment will wonder why he ever put compressed air through a coil of pipe heated in a fire, and will congratulate himself that he did not, like some early experimenters, pass it through a mass of burning coke or charcoal in a tight receptacle.

New York. WM. E. GIBBS.

[The narrative of practical experience here presented is one which our readers will welcome. The letter of our correspondent enforces by practical examples the necessity of avoiding high temperatures in connection with compressed air, or in the air itself. The enforcement of this lesson was the purpose of the previous article to which the writer refers. When attention is thus sufficiently called to the dangerous conditions it is not difficult to avoid them. The suggestion in the last paragraph of the letter as to the danger of re-heating compressed air is commended to the serious consideration of those who are advocating the direct

application of fire for that purpose.—Editor of "American Machinist."]

THE CONDENSATION OF STEAM.

At the ordinary meeting of the Institution of Civil Engineers on November 30, 1897, the paper read was on "The Law of Condensation of Steam," by Messrs. Hugh L. Callendar, M. A., and John T. Nicholson, B. Sc.

In the discussion of steam engine trials it had generally been assumed that the rate of condensation of steam on a surface was practically infinite, so that any surface in direct contact with the steam was immediately heated to the saturation temperature corresponding with the pressure of the steam. It had also been supposed that the amount of condensation under any given conditions was limited, either by the resistance of the film of condensed water to the passage of heat, or by the capacity of the metal or of the circulating water to carry off the heat. In many cases condensation was diminished by films of oil or grease, or by accumulations of air, or by other incrustations or deposits, but these were not considered in the paper.

The authors found, on the contrary, as the result of their experiments on a steam engine running under normal conditions, that a practically clean and dry metal surface was not immediately heated to the temperature of the saturated steam in contact with it, that the rate of condensation of steam was not infinite, but finite and measurable, and that the amount of condensation in any given case was limited chiefly by this finite rate of condensation, and could be calculated in terms of it.

The cyclical variations of temperature in the metallic walls of the cylinder, with each stroke of the engine, were measured by means of thermo-couples inserted at various distances from the inner surface. It was possible thus to deduce the amount of heat absorbed and given out by the metal, and to infer the quantity of steam condensed and re-evaporated at different points of the stroke. The temperature cycles of the steam were simultaneously measured by a very sensitive platinum thermometer.

The observations showed that the temperature of the steam in different parts of the cylinder differed in a systematic way from the saturation temperature as deduced from indicator diagrams.

In order to deduce the condensation from the observed temperature cycles, it was necessary to determine the conductivity and specific heat of cast iron. A series of experiments were made upon a 4-inch bar of cast iron, and the result found for the conductivity was nearly 30 per cent. smaller than that generally assumed.

At the lowest speed of the experiments, namely, forty-five revolutions per minute, the temperature of the surface of the metal at the end of the admission period was found to be never raised higher than within 20 degrees Fahrenheit of the temperature of the steam, and the rate of condensation at any moment was simply proportional to the difference between the temperature of the steam and the surface. The numerical value found for the rate of condensation was 0.74 B.T.U. per second per square foot of surface per degree Fahrenheit of difference between the temperature of the steam and the surface. This was equivalent to the condensation of 27 pounds of steam per square foot per hour at 300 degrees Fahrenheit, for a difference of temperature of 10 degrees Fahrenheit. Assuming this law, the total amount of condensation at any point of the stroke could be inferred by measuring the "condensation areas" on the temperature-cycle diagram, *i. e.*, the areas included between the curves representing the temperatures of the steam and of the metal surface.

To compare the results thus found with the missing steam deduced from the indicator diagrams and the feed measurements, the leakage of the valve and piston was determined as nearly as possible under the conditions of running. It was found to be proportional to the difference of pressure and neary independent of the speed through a considerable range. The usual test for leakage with the valve stationary was found to be of little or no value. From a comparison of leakage tests it was inferred that a valve in motion, however well fitted, was subject to leakage of a definite type. The leakage took place chiefly in the form of water, by condensation and re-evaporation on the moving surfaces, and was

directly proportional to the perimeter of the ports and inversely to the width of the bearing surfaces.

The amount of condensation observed during the admission period in a single-acting non-condensing cylinder 10.5 inches in diameter with a stroke of 12 inches, was only twenty per cent. of the feed at a speed of 100 revolutions per minute. The smallness of this result was probably due to the early compression and the dryness of the steam supply. It was found that re-evaporation was completed very quickly, and that the walls were dry for the greater part of the cycle. It was inferred from the form of the temperature curves, and from other evidence, that the rate of re-evaporation was the same as that of condensation.

From the form of the law of condensation it was possible to make an important theoretical deduction with regard to cases in which re-evaporation was incomplete, and the walls remained wet throughout the whole cycle. Under these conditions the mean temperature of the walls should be the same as the time average of the temperature of the steam to which they were exposed, and the cyclical condensation was the maximum possible for the given steam cycle. If the extent of the clearance surfaces was known, this limiting value of the condensation in any case might be easily deduced from the indicator diagram. If the surfaces were dry during part of the stroke, the condensation was less than the limit, and it was necessary to know the mean temperature of the clearance surfaces in addition.

Upon these views of the nature of condensation and leakage, the missing quantity of steam W in pounds per hour might be expressed by an equation of the general type, $W = S(t' - t^\circ) + L(p' - p'')$,—where the first term represented condensation and the second term leakage, S being the equivalent clearance surface in square feet, and $t' - t^\circ$ the mean difference of temperature, in degrees Fahrenheit, between the walls and the steam during admission reduced to one-half cut-off. L, the rate of leakage per pound difference of pressure $p' - p''$, might be taken to vary approximately as the product of the diameter and the square root of the normal piston speed, for engines of different sizes. It would appear from this formula that the effect of leakage on the perform-

ance was relatively more important in small engines and at high pressures, and that the loss due to condensation was most effectively reduced by increase of piston speed.

As an indirect verification of this law of condensation, the temperature of the clearance surface in cases in which water was present in the cylinder was measured, and was found to agree with that of the mean of the steam cycle. The amount of condensation was also correctly calculated in several cases of published tests in which sufficient data were available. The rate of condensation deduced was also directly verified by an entirely different method. The experiments gave approximately the same rate of condensation and appeared to show that the water drops condensed on the metallic surface, owing probably to their rapid action, did not appreciably diminish the rate. Assuming it possible to estimate the condensation occurring in any given case by the method indicated, from a knowledge of the indicator diagram and of the temperature and area of the clearance surfaces, it then became possible to determine the amount of leakage under the actual conditions of running.—"Engineering."

SPECIAL STEELS FOR SHIP AND BOILER CONSTRUCTION.

On the subject of special steels for ship and boiler construction Mr. F. W. Paul, in his recent presidential address before the West of Scotland Iron and Steel Institute, made some remarks of considerable interest to all concerned in the practical development of ship and boiler construction. There was, he said, a steadily increasing demand for higher grades of steel to comply with the following tests for shipbuilding: Tensile strain, 38 to 43 tons per square inch; extension, 15 per cent. on 8 inches; bends, cold and tempered, to bend to a radius of three times the thickness of the plate. These conditions were equal to what was required in nickel-steel plates, and as the cost of plates of equal quality without nickel was lower, coupled with the ease and certainty of assuring perfectly clean surfaces, governmental authorities and shipbuilders were now principally stipulating for this class of steel plates instead of nickel-steel for construction of

torpedo boats and similar light craft. As an indication of what was being done in this direction, he enumerated tests of normal ½-inch plates, which had lately been manufactured by the Steel Company of Scotland, viz: breaking strain, 58.1 tons per square inch; elastic limit, 39.5 tons per square inch; elongation in 8 inches, 13 per cent.; contraction of area, 35 per cent.

Referring to boiler construction, he said that there had lately declared itself a disposition to use boiler shell plates of a higher tensile strength than previously, some requirements being as high as 35 tons per square inch. For such purposes considerably greater care was demanded in the manufacture of the ingots as compared with softer quality, and it was also essential that the strictest attention should be given to the degree of heat to which the slabs were heated, the amount of work put on in rolling, and also the heat of the plate when the rolling operation was nearly completed. Mr. Paul expressed himself as decidedly of opinion that shell plates of even greater tensile strength than that above referred to could be made with equal degree of safety—just as in the manufacture of higher grade steel for gun barrels, tyres, &c.—but such plates would require special treatment. The commercial necessity of plate mills producing large makes, the keen competition in cutting down prices, were potent factors in adding to the risk attaching to the output of such material.

A NEW COAL CALORIMETER.

At the recent meeting of the American Association for the Advancement of Science a new form of coal calorimeter was described by Mr. C. H. Norton, which has been developed in the Rogers Laboratory of Physics. The apparatus consists essentially of three vessels, each inside the next larger. The space between the outer and the second vessel is filled with water, and is intended to prevent irregular radiation losses. The second vessel placed inside this is about 4⅝ inches in diameter by 6 inches high, and has a loosely fitting cover having holes in it for the oxygen pipes and the ignition wire. The combustion chamber placed inside this is completely immersed in water. It is

2 inches in diameter by 2¾ inches high, and has a screw-top cover. The products of combustion escape from the bottom, where they pass into a flat box, having a spiral division in it. Thence they pass up through a worm, and, finally, out at the top of the calorimeter. The receptacle for the fuel placed inside the combustion chamber takes the form of a platinum crucible, having a hole at the bottom through which the oxygen needed for combustion passes. At about half its height is fixed a diaphragm perforated with numerous fine holes near its edge, serving to support the sample fuel to be examined. The crucible is covered with a tightly fitting perforated cover. A fine platinum ignition wire passes through the sides of the crucible, from which it is insulated by mica, and through the sample of fuel, being finally coupled up to two stout insulated terminals fixed on the wall of the combustion chamber. With this instrument a grain of coal requires about two to three minutes to burn, and needs not more than one-half cubic foot of oxygen. The maximum error due to rise or fall of temperature of the gas, and to evaporation or condensation of moisture, cannot exceed one-third of one per cent. The combustion is effected with absolute completeness, no soot nor carbon monoxide being produced.

AN INSTANCE OF GREAT ECONOMY BY SUPERHEATING.

In a recent Presidential address before the Northern Institution of Electrical Engineers (Great Britain), Mr. J. S. Raworth made the following statement:

Our friends on the Continent have gone a step further; they have improved their engine and improved their steam by superheating to such an extent that I have actually seen a 500-horse power engine driving an average of 300-horse power, fed by a single-flued boiler five feet nine inches in diameter by twenty-six feet long. This impressed me more than the professional tests, which gave 8.8 pounds of steam per indicated horse power. To the saving in coal we must add the saving in boilers and other subsidiary apparatus.

My firm belief is that the economy now being realized in

Germany by Wilhelm Schmidt & Co., is obtained at a lower capital cost, and with less complication, than we find in our Lancashire engines.

HOWDEN SYSTEM OF FORCED DRAFT.

Messrs. James Howden and Co. have during the last twelve months contracted for the application of their well-known system of forced draft to 108 large steamers, having an aggregate I.H.P. of 301,200. When their contracts now in hand are completed, the system will have been applied to boilers supplying steam for 1,640,700 I.H.P., the total number of installations being 655, the power of some of these installations being as high as 30,000 I.H.P.

RAPID COALING IN THE BRITISH NAVY.

The recent coaling record accomplished by the *Magnificent* at Vigo, is, it appears, the best as yet made. The whole of the Channel Squadron was coaling, and most of the vessels averaged over 100 tons an hour. But the *Magnificent's* performance was far and away in front of this, for she averaged over 160 tons an hour, the *Majestic* being a little behind her with 141 tons. In one hour the *Magnificent* took 174 tons, and the *Majestic's* highest record for one hour worked out at 171 tons. Both vessels had to break bulk and "coaled" from one side only, the ship's company filling the bags.

At one time the *Magnificent* was taking in over 3 tons a minute. She commenced coaling at 8 A. M., from the collier *Pontypridd*, carrying 2,038 tons of coal, and finished at 12.50 P. M., having taken in 775 tons in four hours and fifty minutes. The *Majestic* commenced at the same time, but knocked off at 12.35, and took in altogether 670 tons. A few days later the following memorandum was issued to the squadron: "The Vice-Admiral congratulates the squadron on the recent very successful coaling, which has beaten all previous records. *Magnificent*, *Majestic*, *Mars* and *Resolution* very good. The Vice-Admiral considers this record will be improved upon when the gear

demanded for coaling is supplied. Great credit is due to the commanders for their organization, as well as the good working performance by ship's companies. He would impress upon the squadron the necessity of making coaling the most important evolution they are called upon to perform." In the days of masts and sails, "Make all possible sail" was regarded as the premier evolution, but in these modern days of steam and steel, coaling has evidently taken its place.—"Marine Engineer."

In spite of adverse weather conditions, the battleship *Majestic*, preparatory to leaving Lough Swilly for the naval maneuvers, took in 600 tons of coal in less than six hours, or an average of 116 tons an hour, and in one hour she took 138. This is an unprecedented performance in the Channel Fleet, and it has only once been surpassed in the Mediterranean, where on one occasion the *Trafalgar* is said to have taken in some 340 tons at the average rate of 141 tons an hour. To those who have seen a mail steamer coaled at Port Said, where as many as 400 tons have been received in an hour, even this will seem no very remarkable performance, but the coaling of a battle ship from a casual collier alongside is a very different thing from the coaling of a mail steamer at Port Said. There coal is delivered into spacious and readily accessible bunkers by a continuous stream of black humanity, the buckets being filled as soon as they are emptied by another ebony swarm working in an open lighter. In a battleship, all the work is done by the ship's company.—"Engineering."

MARINE ENGINEERING IN 1897.

There is not any prominent feature as to the type of engines, except a fuller recognition of the possible advantages accruing from the adoption of the Yarrow-Schlick-Tweedy system of balancing. In combination with this, the quadruple-expansion system is being more adopted; but the limit is reached in pressure so long as the tank or cylindrical boiler is constructed of steel; 200 pounds or more involves a very heavy shell plate, and for this reason much interest will be taken in the results attained with the

nickel-steel boiler, which Mr. List, of the Castle Line, is having constructed for a steam tug to test this alloy. He has also largely adopted electric motors for machinery in the new *Carisbrooke Castle*. As to water-tube boilers, it can scarcely be said that they have made much progress in popularity in the merchant service in this country [Great Britain], although in the Navy satisfactory results continue to be realized. We hear, however, that it is intended to fit a new London and South-Western Railway Channel steamer with some type of water-tube boiler, and it will be interesting to watch the result, as compared with the Belleville boilers in the Newhaven and Dieppe steamers *Tamise* and *Seine*.—"Engineering."

STEAM CONSUMPTION IN VARIOUS TYPES OF ENGINES.

Dr. Emery, in a table on the cost of steam power, published in the "American Machinist," April 1, 1897, treats of five typical classes of steam engines in general use, and assumes for them certain rates of water and coal consumption which his wide experience guarantees to be approximately correct. The figures which he gives are as follows, per I.H.P.:

	Pounds water per hour.	Pounds coal per hour.
(A) Triple compound condensing engine	14	1.64
(B) Compound condensing engine	18	2.12
(C) Automatic cut-off condensing engine	22	2.59
(D) Automatic cut-off non-condensing engine	28	3.39
(E) Ordinary non-condensing engine	42	5 6

FUEL OIL FOR TORPEDO BOATS.

During the months of December and January just past an apparatus for burning fuel oil instead of coal was installed on the torpedo boat *Stiletto*, at the New York navy yard, under the immediate supervision of Passed Assistant Engineer John C. Leonard, U. S. N., and a number of tests made to show its suitability for use in regular service. The apparatus is that of the Consolidated Gas Fuel Company, using compressed air for spraying the oil. As a result of the test, the apparatus has been permanently in-

stalled, and, if further experience in its use, under the conditions of every-day requirements, proves as satisfactory as there is reason to anticipate, it will doubtless lead to the general use of fuel oil on our torpedo boats.

It may be remarked that this fuel oil corresponds in a general way to the petroleum residuum, or "*astatki*," used in Russia; but, as our crude petroleum has a somewhat different chemical composition from the Russian and the process of distillation is also somewhat different, the fuel oil is not refuse, but that part of the original crude petroleum which remains after the volatile constituents and lighter oils have been removed. The specific gravity is from 0.85 to 0.87, the flash point about 315 degrees Fahrenheit, and the burning point about 350 degrees Fahrenheit. It is, in fact, about the same as a heavy lubricating or cylinder oil without any purification. It costs from two to three cents a gallon at the principal ports on the Atlantic coast. Part of the oil used was supplied by the Fuel Oil Department of the Standard Oil Company and part by the Tidewater Oil Company.

The object of the tests was not so much to determine the increased evaporative value of the fuel oil, as to test it practically, although Mr. Leonard has secured some interesting data, which, it is hoped to publish in a future number of the JOURNAL. His experiments show, however, that, in round numbers, the fuel oil will do twice the work of the same weight of coal. After numerous runs, the burners were perfectly clean and showed no signs of deposition of carbon.

In his last annual report, Engineer-in-Chief Melville discussed the question of liquid fuel, and the following extract is from his report:

The advantages to be derived from the use of liquid fuel instead of coal for certain classes of ships are so great that nearly every naval power has devoted considerable attention to the subject, and has conducted experiments with a view to determining the best apparatus and the necessary conditions. Our country being the greatest producer of petroleum, it is only natural that the subject should have received attention from this Bureau, and from 1867 to the present time the Bureau has, at

intervals, conducted experiments with various forms of apparatus and various kinds of fuel oil, the last having been noted in its report of last year. An experiment on a larger scale has also been authorized by the Department, which, on the recommendation of this Bureau, has made a contract for one of the new torpedo boats to be fitted for burning fuel oil. An exactly similar boat, building by the same contractors, will burn coal, so that an excellent opportunity will offer for a comparison of the two fuels.

That fuel oil has not hitherto been used for naval purposes is due to the items of cost and difficulty of purchase, except in a few localities. On the Caspian Sea, where petroleum refuse is plentiful and cheap, it has been in successful use for more than fifteen years. Experiments made about ten years ago by the Pennsylvania Railway Company, under the direction of Mr. Theo. N. Ely, chief of motive power, showed the entire practicability of burning "reduced oil," but the question of cost made its use, except in special cases, impracticable, as well as the fact that this railway, if using oil fuel to the exclusion of coal, would at that time have consumed more than one-third of the entire output of petroleum in the United States. It is therefore quite evident that, as far as can now be seen, there is no prospect of the use of fuel oil in replacement of coal on vessels employed in general cruising. Inasmuch, however, as the traditional policy of our Navy has been a defensive one, it is probable that our torpedo fleet would operate on our own coast only, so that if we can afford the cost we might readily adopt oil fuel for this class of vessels if, in extended practice, it proves as successful as the experiments lead us to anticipate.

The petroleum refuse or "residuum," already referred to (which closely resembles the "reduced oil" of the Pennsylvania Railway experiments), has been tested so thoroughly that we are able to calculate the effect on radius of action of its use instead of coal. Its evaporative power is from 1.5 to 1.7 times as great as that of coal, and it can be "pulverized" or "atomized" with either compressed air or steam. The use of the latter is the simpler, but involves an extra supply of fresh water to replace that spent in the pulverizers. However, in good forms of apparatus, this amount is less than 2 per cent. of the steam vapor-

ized. A simple calculation will show that in one of our first-class torpedo boats, if enough space be reserved for fresh water to supply the amount lost in pulverizing the residuum, there can still be carried an amount of the latter more than equal in evaporative effect to the total amount of coal now carried. Inasmuch, however, as an evaporator must in any case be supplied for ordinary losses, the simplest way to secure the needed fresh water would be by an increase of evaporator power, with, perhaps, a small reserve tank of fresh water for use at maximum power. If compressed air be used, the weight would probably be less, but the machinery would be more complicated.

The advantages of fuel oil are, greater evaporative power for same weight and bulk, ease of manipulation, perfect control of the combustion to suit the requirements of service, rapidity of starting fires, cleanliness, absence of refuse and the necessity for disposing of it, smaller personnel required in fire rooms, and (if it were in general use) ease and cleanliness in receiving and stowing on board. Against these advantages there are the disadvantages, if residuum is used, of cost (if adopted to a great extent), difficulty of purchase away from our own coasts, and (unless used to a great extent) some trouble in receiving on board. If other forms of fuel oil are used, some of these might be obviated, but the question of danger would arise. The balance of advantages is so great where the use of fuel oil is at all practicable that, in the Bureau's opinion, the Department is fully justified in authorizing the experiments already provided for and any others which will tend to the early practical use of this form of combustible on our torpedo boats and other small vessels.

THE DE LAVAL STEAM TURBINE.

[Reprinted from "Engineering."]

The principal feature of the DeLaval steam turbine lies in the fact that the steam is blown into the buckets through a number of jet nozzles. These nozzles widen towards their outer end, thereby allowing the steam to expand down to the pressure in the exhaust chamber, whilst passing through the nozzles. By

this arrangement the jet acquires a maximum of speed, the full available amount of statical energy being converted into dynamical. The steam passes through the buckets as a free jet, and has no tendency to leak out at the sides. The turbine wheel, in consequence, is able to run quite freely in its casing, the play allowed being, in fact, several millimeters.

The fact that the discharge of steam was, with high pressures, enormously increased when the orifice through which it flowed was divergent, has, of course, long been known, having been discovered by experiment and accounted for by theory, so that the adoption of such a form by DeLaval can hardly be considered a novelty. Further, it was also well known that could the purely mechanical difficulties of construction be overcome, a steam turbine should be extremely efficient. Thus, in 1885, Professor Unwin publicly stated that so soon as the difficulties arising from the excessive limit of speed required were surmounted, we should have "steam turbines smaller, cheaper, and not less efficient than ordinary steam engines." Whilst others have made extremely efficient steam turbines by adopting means for reducing these tremendous speeds to a more reasonable figure, DeLaval has boldly accepted them, and is worthy of the greatest credit for the skill with which he has succeeded in justifying his audacity.

The expansion effected in the nozzle is perfect. The extensive experiments of Professor Zeuner prove that the steam thereby converts into kinetic energy identically the same amount of work as would be indicated in a cylinder, if the expansion were driven far enough to let the indicator diagram end in a point. In addition to this, the expansion is continuous, inasmuch as the steam at any one point of the nozzle is kept constant, so it will be easily understood that any loss of steam through condensation in the turbine has been reduced to a minimum. The only surface where such condensation can arise is in the barrel of the nozzle, the one end being in contact with the cool, expanded steam. The total area of this surface in a turbine of 100 effective horse power, however, only amounts to some ninety square

inches. All the parts of the turbine, in contact with live steam, are well isolated.

Theoretically, the speed of the buckets should be nearly fifty per cent. of the speed of the steam at the mouth of the nozzle in order to attain the maximum efficiency. But for mechanical reasons a somewhat lower figure is adopted, although the speed of the De Laval turbine far surpasses that of earlier constructions. A 5-horse power turbine, for instance, with a diameter of four inches, runs at the speed of 30,000 revolutions per minute; a 50-horse power turbine, twelve inches in diameter, revolves at the rate of 16,000 revolutions per minute, whilst a 100-horse power turbine, of twenty inches diameter, only revolves at the rate of 13,000 revolutions per minute. These high speeds are obtained without being accompanied by vibration, owing to the ingenious adoption of a flexible spindle, to which the turbine is attached. The speed is reduced by gearing down to a suitable degree for direct driving of dynamos, pumps and fans. By means of a counter shaft the turbine will also do service as an ordinary motor for driving shafting, etc. The wheels of the gearing are cut with spiral teeth, so as to combine, the greatest possible strength with smooth running.

The speed is regulated by means of throttling, the steady, even revolution of the turbine, and the momentum of the running parts, making it an easy matter. The varying of the speed can be kept within two per cent., even if the full load is thrown off suddenly. It is, therefore, evident that the turbine is well adapted for the running of dynamos. Besides the turbo-generator, another practical application of the De Laval steam turbine is as a self-contained turbo-pump. These pumps are built as single or double, coupled in parallel or series, the latter giving very high pressure and efficiency. The speed of these pumps is somewhat higher than is the case with centifugal pumps as generally offered, so that it has been possible to reduce the diameter of the pump wheel. This circumstance, coupled with the fact that belt driving has been done away with, renders the efficiency of the pump itself very high. An efficiency of more than seventy per cent. has been obtained with a pump of 5-horse power, running at the rate of 3,000 revo-

lutions per minute. Another adaptation of the De Laval turbine is for fan driving, where equally satisfactory results have been obtained.

In the annexed Table we give the consumption of steam per effective (brake) horse power for different sizes and different pressures of steam, condensing and non-condensing.

The lowest consumption obtained so far was that at a test with a 300-horse power turbo-generator, working at the Edison Electric Illuminating Company, New York. The steam pressure was 150 pounds per square inch, and there was no superheating; vacuum at outlet of turbine, 25.6 inches; steam consumption, 25.84 pounds per kilowatt-hour at full load.

It will appear from the table that the difference in steam consumption when working condensing or non-condensing is unusually high. This is owing to the greater friction against the turbine wheel, when running in a medium of greater density. The increase of passive resistance, when working at high pressure, thus fixes the practical speed still lower than would be determined by the centrifugal force. In some cases, a smaller wheel is used for high pressure work, and a larger one for condensing. From this it will be understood that a turbine arranged to work either with or without condensing, cannot attain to the greatest economy as regards consumption of steam in both cases, the turbine in this respect being in the same position as our ordinary steam engine. Running condensing the passive resistance of the turbine is only small—the actual friction in the bearings being all that need practically be taken into consideration—there being no stuffing boxes, and the turbine wheel running without touching the casing. It is, therefore, claimed for the DeLaval steam turbine, worked with a condenser, that it is an exceedingly economical engine at variable or reduced loads.

A test with a condensing turbo-generator of 33 units running under a steam pressure of 120 pounds showed a consumption of 33 pounds of steam per unit at full load; 33.2 pounds of steam per unit at four-fifth load; 37.3 pounds of steam per unit at half load; 43.5 pounds of steam per unit at quarter load.

The condenser work was included in these figures, the turbine itself driving its own air pump. The turbine was regulated by a centrifugal governor and the throttle valve acting on the inlet steam. The throttling was partly reduced by the shutting off by hand of a certain number of the jet nozzles, the initial steam pressure before the nozzles being:

120 pounds at full load.
120 pounds at four-fifths load (one nozzle shut off).
95 pounds at half load (two nozzles shut off).
75 pounds at one-fourth load (three nozzles shut off).

The simplicity of the construction of the De Laval turbine makes it not only cheap to manufacture, but also reduces the attention required to a minimum. These good qualities have brought about a considerable sale, over eleven hundred steam turbines having from the end of 1892 to May, 1897, been sold from the Swedish Company and the "Société de Laval" in Paris. The aggregate power of these turbines amounted to some thirty-two thousand brake horse power.

At the pumping station of the Exhibition, a 50-horse power turbo-pump was at work, raising the necessary supply of water for various purposes in the Exhibition. This pump could also, in case of emergency, be used as a stationary fire engine, and steam was kept up continuously, night and day.

The separate pavilion of "Aktiebolaget de Lavals Augturbin" contained a very comprehensive and interesting exhibit of four turbo-generators of 66 units each, and two of 33 units each, connected with a high-pressure boiler. This plant was run during the greater portion of the day, yielding light and power to the whole of the Exhibition. The steam pressure was kept at 1,700 pounds per square inch.

The general arrangement of the boilers is quite novel, as they are worked automatically. The coals are stoked continuously from a box above the boiler; this box is filled once every two or three hours, according to the load of the turbine. The stoking boxes in the pavilion in the Exhibition were placed in the gallery. The grate is shaped like a ring, and has a revolving motion. The air necessary for the combustion is forced into the

boiler by means of a fan coupled direct to the gearing shaft of the turbine. The steam pressure acts on the valves of the blast regulating the combustion, according to the quantity of steam consumed.

The steam generator consists of several concentric spirals formed of solid-drawn tube, tested under hydraulic pressure of more than double that of the working steam pressure. The feed water is forced continuously into one end of the boiler, and passes through the spirals one after the other with considerable velocity. The steam generated is submitted to superheating before passing to the turbine. There is no steam chamber or large receptacle whatever in connection with the boiler; this would be impossible owing to the high pressure. The higher the steam pressure the smaller is the specific volume of the steam, and, consequently, the diameter of the tube can be kept small without involving any great loss in pressure from the velocity of the steam in the tubes. It is claimed that the danger of explosion is practically done away with in this system of boiler. In case a tube should actually burst, the steam in the broken part would immediately rush out, and as much steam would continue to do so as could pass through an opening equal to two sections of the tube—one at each end of the fracture—until the boiler had emptied itself of its contents. This quantity of steam is not greater than what can pass through the flues of the boiler into the smoke-stack, without causing any damage whatever.

The exceedingly powerful circulation of the water in the boiler naturally makes the heating surface very effective; this circumstance, coupled with the fact that the spaces for steam and water are very small, has made it possible to bring the dimensions of this new boiler within a small compass. A combination, for instance, of a 100-horse power turbo-generator, with boiler and condenser, occupies a floor space of only 18.9 feet by 11 feet.

The exhaust steam from the turbine is condensed in a surface condenser; from this it is pumped into the hot water receiver and then again fed into the boiler by the feed pump as in marine engines. By means of a special regulating apparatus the feed pump always feeds into the boiler as much water as the turbine

consumes steam; by this arrangement the quantity of water and steam in the boiler and, at the same time, the degree of superheat, are kept constant. At variable loads the fire and pressure of steam are regulated by the blast already referred to. The stoking is regulated automatically according to the rapidity of the combustion through the special construction of the revolving grate. The use of air blast has tended to considerably reduce the dimensions of the smoke stack.

The De Laval boiler is self-contained, requiring no brickwork except the foundation. The air supply passes through an outer shell, whereby it absorbs the radiant heat.

At the Stockholm Exhibition the boilers, as already mentioned, worked at a pressure of 1,700 pounds, the temperature of the steam being about 600 degrees Fahrenheit. The working parts of the De Laval turbine, it should be remembered, only come into contact with cool, expanded steam, by which arrangement very high degrees of superheat have been made practicable, which is synonymous with great economy of steam. After an extended practical experience as to the working of the boiler, we shall publish a complete report of the results as to consumption of steam and coal.

TESTS OF DE LAVAL STEAM TURBINE.

Steam consumption in pounds per brake horse power hour.

Horse power.	Diameter of turbine.		Initial steam pressure.											
			85.3 pounds per square inch.			113.8 pounds per square inch.			142.2 pounds per square inch.			170.7 pounds per square inch.		
	Non-condensing.	Condensing.	Non-condensing.	Vacuum.		Non-condensing.	Vacuum.		Non-condensing.	Vacuum.		Non-condensing.	Vacuum.	
				25.2 ins.	27.6 ins.		25.2 ins.	27.6 ins.		25.2 ins.	27.6 ins.		25.2 ins.	27.6 ins.
	in.	*in.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
5	4	4	50.0	35.9	32 2	46.3	34.8	31.7	43.7	33.7	31.3	41.7	33.1	30.9
20	8	9	46.1	25.6	22.5	42.3	24.5	21.8	39.9	23.8	21.2	38.4	23.1	20.7
50	12	12	40.8	22.7	20.1	37.5	21.6	19.2	35.3	20.9	18.5	33.5	20.3	18.3
100	16	20	28.4	20.9	19.4	35.3	20.1	18.3	33.1	21.6	17.4	31.5	18.7	17.2

UNITED STATES OCEAN MAIL CONTRACTS.

Following will be found a list of the steamship mail contracts made with the United States now in force:

	Per annum.
Route No. 36, "O. M. S." (Contractors Red "D." Line), New York to La Guayra, three times a month, 36 trips a year, of 2,258 miles=81,288 statute miles, at $1 a mile,	$81,288.00
Route No. 57, "O. M. S." (Contractors International Navigation Company), New York to Southampton, once a week, 52 trips a year, of 3,641 miles = 189,332 statute miles, at $4 a mile,	757,328.00
Route No. 69, "O. M. S." (Contractors New York and Cuba Mail Steamship Company), New York to Tuxpam, via Havana and certain Mexican ports, once a week, 52 trips a year, of 2,502 miles = 130,104 statute miles, at $1 a mile,	130,104.00
Route No. 70, "O. M. S." (Contractors New York and Cuba Mail Steamship Company), New York to Havana, once a week, 52 trips a year, of 1,143 miles = 73,476 statute miles at $1 a mile,	73,476.00
Total contract service,	$1,042,196.00

(From "Seaboard.")

SHIPS.

UNITED STATES.

Winslow.—Torpedo Boat *No. 5*, a sister to the *Foote*, of which a description was given in the last number of the JOURNAL, ran her official trial in Chesapeake Bay December 1, 1897, over a course 24.5 knots long, the trial including one run each way. The total time on the course was 1 hour 58½ minutes, and the average speed, corrected for tide, 24.82 knots. The observed machinery data are as follows:

	Starboard.	*Port.*
Steam pressure at H.P. cylinder, pounds	237	248
Steam pressure at I.P. receiver, pounds	79	82.7
Steam pressure at L.P. receiver, pounds	12.4	14.5
Vacuum in condenser, inches	22.75	22.15
Revolutions, main engines	393.3	394.55
Air pressure, in inches of water	2.8	3.75

The draught of water was, forward, 4 feet; aft, 6 feet 7 inches; mean, 5 feet 3½ inches; displacement, 138 tons. The load carried was 24.7 tons, of which 19 tons were coal.

The maximum change of trim at the highest speed was about 3 feet in the length of the vessel.

The conditions of sea and wind were favorable.

For convenience, the principal data of hull and machinery are repeated.

Length on L.W.L., 160 feet; beam, extreme, 16 feet 1⅜ inches; mean draught (normal), 5 feet 3½ inches; displacement, 138 tons; coefficient of fineness (prismatic), 0.396.

Twin screw, vertical, four-cylinder, triple-expansion engines, with cylinders 12 inches, 19½ inches and two of 22 inches diameter by 16 inches stroke; cooling surface in condensers, 1,602 square feet.

Two Mosher boilers with total grate surface of 95 square feet and total heating surface of 5,260 square feet. Designed boiler pressure, 250 pounds.

Total weight of machinery, including boilers, water, stores, etc., 50.82 tons.

Iowa.—The final acceptance trial took place at sea near Sandy Hook on November 16, 1897. The conditions were, as usual, a trial of several hours under natural draft, full power. The following are the average data for two hours, and it is to be noted that the bottom was foul, the ship not having been docked since March 31st.

The regular force in the Engineer Department was employed without assistance from deck force. It is interesting to note the power developed and the amount of coal burned per square foot of grate, which show the benefit of the tall smoke pipes of the *Iowa*, which are 100 feet in height above the grates.

Trial of U. S. S. *Iowa*			November 16, 1897.
Speed, knots			13.2
Wind, force 4; direction, ahead to quarter. Sea, smooth.			
		Starboard.	*Port.*
Revolutions main engines, per minute		91.4	92.6
Steam at boilers, pounds		144	144
Steam at engines, pounds		142	142
Steam at 1st receiver, absolute, pounds		49	50
Steam at 2d receiver, absolute, pounds		18	19
Vacuum, inches		25	26
I.H.P.	H.P. cylinder	1,281.1	1,434.5
	I.P. cylinder	1,519.6	1,347.6
	L.P. cylinder	1,342.2	1,197.4
	Main engines only	4,142 9	3,979.5
	Main engines and auxiliary machinery	8,227.4	
Coal per hour, pounds		18,100	
Coal per hour, per square foot grate, pounds		25.2	
Coal per hour, per I.H.P., pounds		2.2	
Grate surface in use, square feet		756	
Heating surface in use, square feet		24,082	

Draft, forward, 22 feet 6 inches; aft, 24 feet 7 inches; mean, 23 feet 6½ inches; displacement, 11,080 tons.

Foote.—The recent experience of this torpedo boat has been unfortunate. The machinery was given a thorough overhaul at New York, during which the effect of a very small amount of grease in condensers of the small size on torpedo boats was shown.

The tubes were all thoroughly cleaned, and the amount of grease was said not to be as much as a teacup full, yet this had prevented the securing of a vacuum greater than a few inches. After cleaning, it was 23 inches. On her trip south to join the other boats of the torpedo flotilla, the tubes of one boiler were so badly burned, owing to low water, that she was sent to Norfolk, where the boiler was retubed. The trip south was resumed, but did not last very long, for at Charleston, while going out of the harbor, the starboard propeller shaft was broken. This was removed at Port Royal, and she proceeded to Norfolk under the other screw, where she is now having a new shaft put in.

Porter, Du Pont, Winslow.—These three boats have been crippled temporarily by the breaking of the hanger strut to one propeller shaft in each boat. The reason is not definitely known, but it is thought that it may have been due in part to racing of the engines in heavy weather. While it has not been intended to try the boats in exceptional weather, it was desired to see if they could stand moderately rough weather at sea. It is evident that the usefulness of these fleet little craft will be very limited if they can operate only in smooth water. Except the breaking of these struts there has been no trouble thus far except on the *Foote*, and it is probable that when stronger struts are fitted they will not again give out.

Maine.—A disaster far more appalling in loss of life as well as property than that at Samoa in '89 is the destruction of the second class battle ship *Maine*, which occurred in the harbor of Havana on the evening of February 15th. At 9·40 P. M. there was an explosion in the forward part of the ship which resulted in her complete loss. Owing to the location of the explosion, all of the officers except two escaped, while 256 of the men were killed by the explosion or drowned. The accounts thus far published do not explain the cause of the explosion, which is believed to have been one of the magazines. A court of inquiry has been ordered, and after its investigation the cause may be known. Divers are to be sent at once to inspect the wreck.

Marietta.—The following interesting data of the performance of this vessel are from an official report received at the Navy

Department from Passed Assistant Engineer W. H. Chambers, U. S. Navy, the chief engineer:

	I.	II.	III.	IV.
Boilers in use	A & B	A & B	B	B
Duration in hours	47.97	63.75	47.63	35.55
Distance, patent log, knots	507.7	609.6	453.7	304 8
Mean speed, patent log, knots	10.58	9.56	9 53	8 57
Mean revolutions, main engines	181.1	160.5	160 0	140 3
I.H.P. main and auxiliary machinery	549 5	371.2	360.0	273 8
I.H.P. auxiliary machinery (estimate)	18.0	16.0	17 0	17.0
I.H.P. main engines only	531.5	355.2	343 0	256.8
Coal for all purposes for run, tons	26.60	27.36	17.90	9 46
Coal for auxiliary machinery, including evaporator, blowers, and heating ship (est)	3 60	5 55	4.00	3 30
Coal for main engines for run	23.00	21.81	13 90	6 16
Coal for main engines per day	11 50	8 20	7.00	4.15
Coal for main engines per I.H.P.*	2.02	2 16	1.91	1.52
Auxilaries in use	Two main circulating pumps; one boiler feed pump; one dynamo; one F. & B. pump; steering engine. All of the above constantly.			
	Heating ship.	Heating ship about half the time; evaporator 0.6 time.	2 ventilating blowers 0.5 time; evaporator 0.5 time.	2 ventilating blowers 0 5 time; evaporator 0.5 time.

* As these figures depend on two estimates, it will be understood that they are only approximate.

AUSTRIA.

Buda-Pest, Monarch and **Wien.**—The Austro-Hungarian coast defence ironclad *Buda-Pest* has recently completed a successful series of official steam trials at Pola. The Austrian Navy now possesses three coast defence ironclads, namely, *Wien*, *Monarch* and *Buda-Pest.* These vessels have been constructed from the designs of Herr Oberingenieur Siegfried Popper, of the Austrian Navy, and are in every respect similiar excepting the boiler installation. The *Wien* and *Monarch* are fitted with cylindrical boilers, and the *Buda-Pest* with Belleville

water-tube boilers. All three vessels were tried at Pola, each loaded to the same displacement and run over the same course, the trials being under the observation of the same Austrian naval officers forming the commission representing the Government. The principal dimensions of the vessels are as follows: Length, 305 feet; breadth, 55 feet 9 inches; draught, 21 feet; displacement, 5,550 tons; armor belt, 10.6 inches; barbette, 10.6 inches; protective deck, 2.36 inches. The armament consists of four Krupp, 9.4-inch B.L.R.; six quick-firers, 5.9 inches; fifteen quick-firing 3-pounders; two machine guns; two torpedo-tubes.

The machinery consists of two sets of triple-expansion engines having cylinders: High pressure, 33½ inches; intermediate pressure, 51 inches; low pressure, 78¾ inches; stroke, 35½ inches; steam being supplied, in the case of the *Wien* and *Monarch*, by cylindrical return-tube boilers, having a total heating surface of 15,750 square feet, and grate area of 568 square feet, and in the *Buda-Pest* by Belleville water-tube boilers, having a total heating surface of 22,500 square feet, and grate area of 720 square feet. The propellers of the three vessels were of the same diameter and surface, pitch being 15 feet 6 inches in the case of the *Wien* and *Buda-Pest*, altered to 15 feet 3 inches in the case of the *Monarch*. Appended are comparative results of the natural and forced-draft trials of the three vessels.

Natural draft trial of six hours' duration:

	Wien.	*Monarch.*	*Buda-Pest.*
Mean number of revolutions	121.7	119.8	124
Mean indicated horse power	6,376	6,110	6,608
Mean steam pressure in boilers, pounds per square inch	138	130	230
Ditto, at engines	132	121	129
Vacuum	26.4	27	27.9
Mean air pressure	.63	.6	nil
Mean speed of ship	16.7	16.2	17.1

Full-power, forced-draft trial, four hours' duration, during two hours of which the vessel steamed over measured course of 17 knots, accurate observations being taken as to power, speed, etc.:

	Wien.	*Monarch.*	*Buda-Pest.*
Mean revolutions	131.2	135 76	135.6
Mean indicated horse power	8,480	8,900	9,185
Mean steam pressure in boilers, pounds per square inch	149	145	199
Ditto, at engines	142	131	149
Vacuum	25.5	25.5	26.4
Mean speed in knots	17.49	17.35	17.87
Number of ventilating fans (stoke-hold)	8	8	4
Mean air pressure	1.75	1.75	.20

The stokers were drawn entirely from the Austrian Navy. The coal used was Nixon's Navigation, and, being measured in the case of the natural-draft trial of the *Buda-Pest*, the consumption was ascertained to be about 1.8 pounds per indicated horse power. Thermometers were placed in various parts of the engine and boiler rooms, between decks and in the cabins. The temperature registered during the trial was carefully noted, and was found much lower in the case of the *Buda-Pest* than her sister vessels. The representatives of the Austrian Government considered the results of the trials as highly satisfactory, both engines and boilers working smoothly throughout. It will be observed that the adoption of Belleville water-tube boilers enabled such a large increase of heating and grate surface when fitted in the same space as the cylindrical boilers, that a higher power and speed could be realized under practically natural-draft conditions than could be obtained with the cylindrical boiler under forced draft with considerable air pressue. The Stabilimento Tecnico Triestino, of Trieste, were constructors of the vessels and engines, Messrs. Maudslay, Sons and Field being responsible for the boiler installation, and they were represented at the trials by Mr. John Sampson. It has been decided to fit Belleville boilers in the new armored vessels which are building for the Imperial Austrian Navy.

CHINA.

Hai-Tien.—The first-class protected cruiser *Hai-Tien*, built to the order of the Chinese Government, was launched on the 24th of November, 1897, from the Elswick shipyard of Sir W. G. Armstrong, Whitworth and Co. The principal dimensions of the vessel are as follows: Length, 396 feet; breadth, 46 feet 8 inches;

mean draught, 16 feet 9 inches; displacement, in tons, 4,300. Her armament will consist of two 8-inch Elswick quick-firing guns, ten 4.7-inch Elswick quick-firing guns; twelve 3-pounder Elswick quick-firing guns, four 37-millimeter Maxims, six rifle caliber Maxims, and five 18-inch torpedo tubes. The vessel will have a strong steel protective deck, extending forward and aft, so as to protect completely the machinery, magazines and steering gear, the deck varying in thickness from 1½ inches on the flat to 5 inches on the slopes. The conning tower will be built of armor 6 inches thick, so as to afford sufficient protection to the steering wheels, &c., when the vessel is going into action. The total coal capacity is about 1,000 tons, and the speed guaranteed on trial is 24 knots during a trial of four hours' duration.

Hai-Chai.—A sister vessel to the *Hai-Tien*, was launched from the same yard on January 24th.

ENGLAND.

Crane.—The fifth of the 30-knot torpedo boat destroyers delivered by Messrs. Palmer, of Jarrow-on-Tyne, carried out her first official trial at Portsmouth, on December 10, 1897, with satisfactory results. The weather was hazy and the sea smooth, but the wind, when the *Crane* was steaming against it, was strong. During the last hour the engines were worked up to more than 400 revolutions a minute, but the mean of the three hours was 395.5, giving a speed of 30.138 knots. The mean of six runs on the measured mile gave a speed of 29.62 knots, but the highest speed past the mile was 32.75 knots. While the vessel was running on the mile the air pressure was 2.9 inches and the vacuum 25.2 inches. The principal condition of the trial was that she was to make 30 knots with a coal consumption of 2.5 pounds per unit of power per hour; but, though the consumption was not worked out, it is believed to have been economical. The engines maintained a mean of 6,428 horse power, working smoothly, while there was an entire absence of vibration.

Express.—Messrs. Laird Brothers, Birkenhead, launched, on the 11th of December, the torpedo boat destroyer *Express*, which

is larger than any destroyer hitherto built. Her length is 235 feet, and she is designed to have a speed of 33 knots, which will make her the fastest vessel afloat.

Fame.—The *Fame* is 210 feet long over all, the maximum beam being 19 feet 6 inches and the depth 13 feet 6 inches. In other respects she closely resembles the *Daring*. The form of stern is that peculiar to the Thornycroft design, in which the after part of the vessel is flattened under water, the propellers, of which there are two, being under the bottom. The engines are of the four-cylinder, triple-compound type Messrs. Thornycroft have designed for vessels of this class. The engines of the *Fame* are, however, somewhat more powerful than those of the *Daring*, the cylinders being 20 inches, 29 inches, and two of 30 inches in diameter, with a stroke of 18 inches. There are three Thornycroft water-tube boilers of the *Daring* type, but these are naturally somewhat larger than those of the latter craft, in order to give the increased power required for the higher speed of the larger vessel. Two of these boilers are forward with a chimney in common, and one amidships with a single chimney.

The gun armament of the *Fame* is somewhat more powerful than that of the earlier vessels. There are five 6-pounder guns, two more than in the *Daring*. On the other hand, there are but two torpedo discharges, both of which are placed aft. The *Daring* had, in addition, a bow discharge, but the naval authorities consider this unnecessary for the later boats. No doubt, in the arrangement of the armament, the newer vessels more nearly fulfill the conditions suggested by the name of their class, and become more nearly torpedo boat destroyers rather than torpedo boats.

The *Fame* gave an excellent result on her trial trip, which was run on the Maplin measured mile. The draught forward was 5 feet 1½ inches; aft, 7 feet 1 inch, and the speed was 30.155 knots. The boiler pressure was 205 pounds per square inch; the air pressure in the stokehold, 4 inches; and the vacuum averaged 26.3 inches. The revolutions were 394.8 for the starboard, and 393.1 for the port engines. The mean indicated horse power in the starboard engines was 2,914, and in the port engines, 2,980,

or a total of 5,894 indicated horse power for both sets of engines. The *Fame*, it will be seen, did not reach quite the speed attained by the *Desperate*, the latter vessel making, on unofficial trials, 30.46 and 31.035 knots, with a load of 15 tons on board in place of 35 tons.

Hannibal.—Has completed her trials. On the conclusion of her thirty hours' coal consumption trial, the draught of water forward was 25 feet and aft 25 feet 8 inches. The vacuum was 28 inches, and the revolutions 84 per minute. The mean horse power was 6,124, which gave the ship a speed of 14.6 knots. The coal consumption worked out at 1.78 pounds per unit of power per hour. On the eight hours' natural draft trial the draft of water forward was 24 feet 9 inches and aft, 25 feet 9 inches. She had 150 pounds of steam to the square inch in the boilers, the mean air pressure being .26 inch, and the vacuum was 27 inches. The collective indicated horse power with 97 revolutions was 10,357, and the speed by patent log 16.3 knots. The coal consumed was 1.97 pounds per unit of power. On her four hours' forced draft trial she drew 24 feet 8 inches forward and 25 feet 4 inches aft, and the vacuum was 27 inches. With 12,138 indicated horse power and with 103 revolutions she gave a speed of 18 knots and a coal consumption of 2 pounds per unit of power per hour. Messrs. Harland and Wolff, Belfast, built the engines.

Heron and **Jackdaw.**—H. M. ships *Heron* and *Jackdaw*, light-draught gunboats, built by Messrs. Yarrow and Co., have been re-erected at Warri on the Niger River. Engineer T. S. Guyer, R. N., and four engine room artificers were detailed by the admiralty to gather as much knowledge as possible as to the construction of these vessels for a short time before the *Frutera* left. On arrival at Forcados the *Frutera* proceeded to Warri, some 50 miles up the river. Some 60 men of all grades have been engaged in the work of construction. Of these 30 are Kroomen. Both vessels have been put together, their machinery tried under steam, and guns mounted and ready for action in 34 working days. The vessels were put together in a 5-knot current. They were coaled, by advices of December 7, and ready to proceed,

and as they were tried on the Thames, and easily obtained their contract speed while burning wood, they will be independent of coal supply.

Illustrious.—The results of the 30 hours' coal-consumption trial of the *Illustrious*, battleship, built at Chatham, are as follow: Draft of water, forward, 25 feet 7 inches; aft, 26 feet 6 inches; speed, 14.51 knots; steam pressure in boilers, 142 pounds per square inch; revolutions, 83.1 starboard, 83.0 port; horse-power, 3,101 starboard, 3,054 port—total, 6,155; coal consumption, 1.77 pounds per indicated horse power. She again left the Nore on the 16th of December for her eight hours' natural draft-trial. When the vessel was off Dover, and while the engines were being worked up for the trials, the induced draft fans broke down, causing such damage as to necessitate the postponement of the trials. The *Illustrious* returned to Sheerness.

Pelorus.—On her recent seventy-two hours' run, the *Pelorus* proved herself to be an exceedingly smart little vessel. She was favored with good weather from the day she started on the trip until within a few hours of her reaching harbor. She managed to get across the Bay of Biscay in fine weather, and was running down the Spanish coast two days later. She continued her course until a little to the north of Cape St. Vincent, and then turned. For the first twelve hours of the seventy-two she averaged 16.42 knots, running a total distance of 197 miles with 3,516 H.P. For the last sixty hours she averaged 17.3 knots, running a total distance of 1,038 miles with a H.P. of 4,277.8. Thus she covered a total distance of 1,235 miles in the seventy-two hours, the average speed for the whole journey being 17.15 knots. The total coal consumption for all purposes was 305 tons. The coal consumption was rather high, but, doubtless, a good deal was used for other purposes than propulsion. She could have evidently kept up a knot more than this as long as her coal supply held out, proving herself a vessel not to be despised even in these days of high speeds.

Pomone.—Was laid down on December 21, 1896, and launched from the building slip at Sheerness dockyard, on the 26th of November, 1897. She is of steel, and is 300 feet long by 36

feet 6 inches wide, with a displacement of 2,135 tons, engines of 7,000 horse power, and an armament of eight 4-inch quick-firing guns, eight 3-pounder Hotchkiss guns, two .45-inch Maxim guns, and two torpedo tubes. Her machinery will be supplied and fitted by Messrs. John Penn and Sons.

Porpoise.—Went on her three hours' commissioning trial on December 7th. The draught of water forward was 13 feet 11 inches, and aft 16 feet 3 inches. The steam in the boilers was 128 pounds to the square inch, and the vacuum was 24 inches. The *Porpoise* was only required to develop 2,200 horse power, but 2,235 horse power was realized, and produced 127.8 revolutions, which gave a speed by patent log of 14.8 knots.

Powerful.—The steaming programme of H.M.S. *Powerful*, en route to China, has afforded an excellent opportunity for ascertaining the capacity of the cruiser for keeping the sea for a length of time, while steaming at the full power of her engines and boilers. From 12 to 13 knots will be her speed from the Cape to Singapore, but from Singapore to Hong Kong, a distance of about 1,450 miles, her machinery will be running at as near full power as possible, and she will make an effort to do the journey at an average speed of over 20 knots. She will doubtless carry only as much coal as was specified for her designed draught, as her speed would be considerably lessened by her increased depth in the water if her full coal capacity was utilized. Of course, she will be able to make better progress at the depth of her designed draught, in which case she will be able to carry 1,500 tons of coal. The result of the trip from Singapore to Hong Kong will be awaited with considerable interest, especially the amount of coal she consumes each day. It is supposed that for the continuous journey of 1,450 miles she will develop about 23,000 I.H.P. Taking her second thirty-hour coal consumption trial as a criterion, it is estimated that the quantity of fuel she will use will be 1.83 pounds per I.H.P., or 41,175 pounds for 22,000 I.H.P., that is, 1,470 tons for the three days' run. The quantity of coal she carries at her designed draught is 1,500 tons, and even supposing she uses 2 pounds per I.H.P. per hour, she need only carry

an extra hundred tons, so that the increase in her designed draught need not be much.

Sheikh, a twin-screw river gunboat, 145 feet long by 24 feet 6 inches beam (a sister ship to the *Sultan*, which is now in Egypt), constructed by Messrs. Yarrow and Co., Limited, had her official two-hours' speed trial in the River Thames on the 4th of November. The draught was only 2 feet, carrying a load of 35 tons, and the mean speed for the two hours was 11.466 knots, equal to 13.177 statute miles, with only 140 pounds steam. The boilers are able to work at 200 pounds, so that a considerably higher speed could have been maintained, if wished. This vessel is one of several building to Admiralty designs for use on very shallow rivers. The armament consists of two 12-pounder quick-firing and several automatic guns.

Star.—The torpedo boat destroyer, *Star*, had a preliminary trial of her machinery at Portsmouth on December the 16th, but as the engines worked so satisfactorily, maintaining, with 394 revolutions, a speed of 30.66 knots for three hours, it was decided to accept the trial as official. She was the first of the 30-knot destroyers delivered at Portsmouth by the Palmer Shipbuilding Company, and at her initial trial the starboard low-pressure cylinder broke, necessitating the re-engining of the vessel.

Her second stipulated speed trial was conducted at Portsmouth on December 22d, the mean speed of the three hours being 30.68 knots, while in the last half hour she ran at a speed of 31.9 knots. She also carried out her stopping, starting, and circling (ahead and astern) trials, all of which proved highly satisfactory. The *Star* is the fifth 30-knot destroyer built and engined by the Palmer Shipbuilding Company that has completed her trials at Portsmouth, and the *Flying Fish*, which has been delivered, will be run early in the New Year.

Venus.—The cruiser *Venus*, on a run down the Channel recently, carried out two trials—one of three hours at full power, and one of thirty hours at one-fifth power—in order to compare her results with those of the *Arrogant*, which is fitted with Belleville boilers, the *Venus* having cylindrical boilers. On the three hours' trial she realized, with 8,200 indicated horse-power, a speed of 19.6 knots,

and on the thirty hours' trial, with 1,920 indicated horse power, a a speed of 13 knots. On the first trial the coal consumption was not taken, but on the second trial it worked out at 2.1 pounds per unit of power per hour for the main engines, and 0.4 pound for the auxiliary engines. In the *Arrogant* the result was 2 pounds for the main engines, and 0.8 pound for the auxiliary engines, giving for the main engines practically the same economy; but further trials are to be made with the *Arrogant*.

Violet.—The torpedo-boat destroyer *Violet*, built and engined by Messrs. Doxford, of Sunderland, had her initial three hours' full-power trial at Portsmouth on the 3d of December. The mean indicated horse power of the three hours was 6,200, but the mean speed of the three hours and of the six runs on the measured mile was 29.7 knots, instead of 30 knots as required by contract.

New Royal Yacht.—The contract for the construction of the machinery for the new royal yacht has been given out by the Admiralty to Messrs. Humphreys, Tennant and Co., London. The engines have been designed to develop 11,000 I.H.P. on a trial of eight hours' duration, when the speed is expected to be 20 knots. The vessel is to be 380 feet long between perpendiculars, 50 feet beam, and 18 feet draught, at which the displacement will be about 4,600 tons. The first keel plate was laid at the Pembroke Dockyard on December 16, 1897. More than usual care will be taken in respect of sub-division into water-tight compartments, to prevent sinking in the event of collision or other mishap. The hull will be sheathed with wood, and covered with copper, to obviate the necessity of frequent docking.

The engines will be of the triple-expansion four-cylinder type, with four cranks, and balanced on the Yarrow-Schlick-Tweedy system. There will be two sets driving twin screws, and each will have one high-pressure cylinder, 26½ inches in diameter, one intermediate, 44½ inches in diameter, and two low-pressure cylinders, each 53 inches in diameter, the stroke in each case being 39 inches. The cooling surface is 12,000 square feet. At 11,000 H.P. the engines will be running at 140 revolutions per minute, equal to a piston speed of 910 feet per minute.

Steam is to be supplied from eighteen Belleville boilers, de-

signed with the new economizer, and, in accordence with recent practice, the tubes in the main boiler will be 4 inches in diameter, and those in the economizer in the uptake will be 2¾ inches in diameter. The total heating surface will be about 26,000 square feet, and the grate area 840 square feet. The boilers are to work at a pressure of 300 pounds to the square inch, but this will be reduced with the usual valve to 250 pounds at the high-pressure cylinder. The total weight of the engines is to be 950 tons when ready for steaming. There are to be three funnels and two masts.

It may be interesting to have, for purposes of comparison, a few particulars of the engines of the present yacht, the *Victoria and Albert*, which are as follows: The engines, which consist of a pair of oscillating cylinders, each 88 inches in diameter and 7 feet stroke, are of 600 N.H.P., and indicate 2,980 H.P. The pressure in the boilers is 23 pounds per square inch, and when the engines make 25.4 revolutions per minute, they propel the vessel at a speed of 17 knots per hour. The paddle wheels are 30 feet 11 inches diameter over all, and at the above speed give 18 per cent. slip.

The new yacht is not to be ready for some time, in fact the engines are not to be delivered till the early part of 1899.

Thrasher.—The following account of the standing of this torpedo-boat destroyer and of the injuries sustained is abridged from one in "Engineering" for November 26, 1897, which has some very interesting illustrations.

The *Thrasher*, like the *Lynx*, was built at Birkenhead by Messrs. Laird Brothers. She is one of the later and larger 30-knot destroyers, being 213 feet 6 inches long and 21 feet 7 inches wide. Her displacement is about 300 tons, and her indicated horse power about 6,000. Her complement is 58 men. She is, however, exceeded in size by vessels of the same class more lately put in hand. On September 29 the two vessels, whilst cruising from St. Ives to Falmouth, the *Thrasher* leading, ran on the rocks, there being a thick fog at the time. There is some doubt as to the speed at which the vessels were steaming before breakers were seen. Previously the speed had been 12 knots. The signal had been made to reduce this to 10 knots, but the vessel went ashore before it was

hauled down. The officer of the watch on board the *Thrasher* estimated that the speed when the vessel actually struck was about 7 or 8 knots, and that the engines had then been going astern ten seconds. On a previous occasion the vessel had been stopped in about two of her own lengths when going at 12 knots. We are not now concerned as to the cause of the accident, but only with its effect, but the speed at the time of striking has a material bearing on the latter.

All estimates made under such conditions, even by the most competent observers, must be of a very uncertain nature, but probably the estimate of 8 knots does not undervalue the speed. The damage sustained by the bow of the boat was characteristic of accidents of this kind, the hull structure being crumpled up. The main part of the energy due to the forward movement of the vessel was apparently absorbed by the bending of the hull structure in the immediate neighborhood of the stem, but at the same time the boat evidently was carried up on the rocks in her fore-part. Up to a point about the neighborhood of the forward bulkhead, the bottom was entirely crumpled up, and then for a short distance the damage was of a more partial character. At a point under the forward boiler there was, however, a large indentation, and this was so pronounced that the boiler was somewhat displaced. We have, on previous occasions, when dealing with accidents of a similar nature, pointed out the remarkable toughness or ductility of vessels built of mild steel, and the manner which they undergo violent usage with comparatively small result. We need not here repeat what has formerly been said, and which has now become one of the commonplaces of naval construction. The present accident is, however, an extreme instance of its kind, not only from the fact that the *Thrasher* went aground on a shore of the most trying character, but also because of the very light structure of the vessel.

This very lightness, which is often looked upon as a source of weakness, is, however, to some extent, an element of safety. The Admiralty have introduced into the design of these vessels a water-tight flat forward, which is just above the water line, and extends aft as far as the machinery space. In later

designs the after part has also been provided with a water-tight platform of a similiar nature. This is an expensive addition to the design, being very troublesome to fit, as it has to cross the frames, etc., and be made water-tight to the skin plating; but it gives to the vessel an element of safety equivalent to a double bottom throughout the part over which it extends. In the case of the *Thrasher*, the wisdom of this provision was well illustrated; for, though the vessel was so completely crumpled up in her forward part, the water-tight flat was not so seriously injured but that the water could be kept from passing it sufficiently to enable the vessel to be taken round to Devonport, after such provision had been made as was possible on the spot. It is in this respect that the flexibility of the hull structure—a feature in vessels of Her Majesty's Navy which has on occasion been adversely commented upon—is found to be of value. If the whole forward structure had been of a stiff and solid nature, the vessel might not have gone so far on the rocks, and the damage might have been more localized, although this is by no means certain; but there is no doubt that such damage as existed would have been of a more radical nature. It will, perhaps, be remembered that in the case of the *Apollo's* mishap, the only sign of damage to the inner bottom was due to the rigid casing of a Kingston valve, which acted as a stiff strut and carried the impact of the blow to the inner skin. In the case of the *Thrasher*, the ordeal was so trying that some of the riveting of the water-tight flat was damaged, but the injury was remarkably small, considering the circumstances.

The most interesting feature about the condition of the hull is, however, an indentation, which might be described as a channel, running right down the side of the vessel. This extends to the keel, and on the other side there is a bulging out exactly corresponding to this bulging in. On deck the plating was forced upwards, and creased in an athwartship line. This damage was at the boiler compartment, about midway between two boilers, and was caused by the lifting of the forward part of the vessel as her bow was forced upon the rocks, whilst her after-part was waterborne. Whether wave action on the after-part had anything to

do with the result can not be determined, but there is reason to suppose that there was twisting action from some cause. In the boiler compartment there are the usual fore-and-aft bunkers on each side, the walls of which extend from deck to bottom, and form an inner skin, which greatly strengthens the hull. The structure is further stiffened by angle bars worked longitudinally about half way down. These were bent, as was the skin plating, but the latter was not fractured, although there was some leakage, not of an excessive nature, due to strained rivets.

It was this giving of the main structure of the hull, however, which caused the lamentable loss of life that attended this disaster. The two circular openings to the stokehold, one on each side, are on the line of damage, and the deformation was so great that one of these manholes was almost closed by the bending of the hull, so much so that it was only just possible to get a hose through the opening after the accident. On the other side the opening was not seriously deformed; but near here, unhappily, the steam pipe from the boiler passed, and this was rent across by the the strain put upon it. The men in the stokehold, therefore, had only one means of escape, that being up a steep ladder, and near the top of this an enormous volume of steam was escaping.

It will be seen that as the vessel ran up the rocks she was undergoing stresses the reverse of launching stresses, that is to say, she was subjected to sagging. So violent was this that the keel has been permanently altered in length 3 inches to 4 inches, and the temporary compression at the deck was no less than 14 inches. This was shown by the marks left through two parts of the fittings, normally 14 inches apart, coming in contact, and the fact was supported by the shutting up of the manhole. One of the engine room staff, it may be here stated, had a most providential escape. He was coming on deck, and had just got his legs clear of the opening, when the boat went ashore and so closed the exit through which he just passed.

The way in which the hull reverted, to a large extent, to its normal shape—putting aside local damage—is remarkable. When the vessel was got off the rocks the manhole opened

again, and after she had been docked she almost recovered her general form, a practical proof of the elasticity of these light steel structures not often afforded. The ease with which the repairs have been executed is another reassuring feature, which may have some significance in time of war.

Putting aside the sad loss of life and injury to the crew, the accident to the *Thrasher* may be regarded as an event not altogether to be deplored. It has emphasized a danger of which we were formerly aware, but of which we may with profit be reminded, that of risk of damage through broken steam pipes, although the fracture of the *Thrasher's* steam pipe was due to a circumstance against which provision could hardly be expected to be made. We see, however, that these light and swift vessels are built with material of the highest character, and that the workmanship by which they are put together is equally good. It is further illustrated that though these craft are wonderfully light, the material is so well distributed that they will go through the most trying ordeal to which they could be well subjected without sustaining such damage as cannot be made good in a few weeks. Perhaps there is a source of congratulation to be found even in the saddest feature of the case. The conduct after the accident of all concerned in the matter, the crews of both vessels, and those who were engaged in the salvage operations, reflects the highest credit on the Navy, and shows that the old traditions of the service are upheld to the present day. Especially is this the case of the stoker Lynch. He had escaped on deck himself, but on finding that his mate was not so fortunate, he heroicially descended into the stokehold again and brought out his scalded companion. The latter died from his injuries; but Lynch, we are glad to say, is recovering, though slowly, he having been terribly scalded, so much so that he is, we believe, never likely to get over the effects. It is sad to think that an untoward incident, such as the closing up of one manhole, should have deprived these two men of that chance of safety which the two openings were expressly intended by the designer of the vessel to afford.

Argonaut.—On January 24, the Fairfield Shipbuilding Com-

pany, Govan, launched H.M. first-class cruiser *Argonaut*, which is one of four at present under construction for the British Government. The *Argonaut's* dimensions are: Length over all, 462 feet 6 inches; length between perpendiculars, 435 feet; breadth, extreme, 69 feet; displacement, 11,000 tons. The hull is built generally of Siemens-Martin steel. Under and above the protective deck, for the length of the boiler space, compartments are formed by longitudinal bulkheads for stowage of coal, and these compartments, with cross-bunkers, form a complete coal protection to the boilers. The coal capacity at normal draught is 1,000 tons, but provision has been made for carrying about twice that quantity should occasion require. The *Argonaut* will be rigged with two masts, each fitted with a platform for working electric search lights, and all the usual signaling appliances. She will be fitted with four funnels, and her appearance will resemble precisely that of the *Diadem*, which is now undergoing her steam trials. The *Argonaut's* engines will develop 18,000 horse power, giving a speed under natural draft of 20.75 knots. Her armament will be two 6-inch guns in casemates, four 6-inch guns in shields, four 12-pounders, three 3-pounders, eight Maxim machine guns, and two 18-inch submerged torpedo tubes. [There is evidently an error in the description of the battery. See that of the *Diadem* on page 241 of this issue.—ED. JOURNAL.]

Locust.—Torpedo-boat destroyer, built by Messrs. Laird Brothers, Birkenhead, went out on January 21st for her official full-power coal-consumption trial at 30 knots, with very satisfactory results. The speed realized on six runs on the measured mile at Skelmorlie was 30.26 knots, as follows:

	Time.		
	min.	*sec.*	*Speed.*
First mile	2	$0\frac{3}{5}$	29.90
Second mile	2	0	30.00
Third mile	1	$58\frac{4}{5}$	30.30
Fourth mile	1	$58\frac{3}{5}$	30.35
Fifth mile	1	$57\frac{2}{5}$	30.66
Sixth mile	2	$0\frac{1}{5}$	29.80

And for three hours continuous steaming, 30.15 knots.

Seal.—Her sister ship, the *Seal*, completed her series of trials on the 24th of January in the presence of the Admiralty representatives. Her official full-speed trial was commenced shortly

after 10 A. M., and a speed of 30.79 knots was obtained as a mean of the six runs on the measured mile. The individual results were as follows:

	Time.		
	Steam.	*min.*	*sec.*	*Speed.*
First mile	210	2	0	30.00
Second mile	225	1	53	31.86
Third mile	217	1	58⅖	30.46
Fourth mile	207	1	55⅕	31.25
Fifth mile	204	2	1½	29.71
Sixth mile	203	1	58⅖	30.46

The mean speed for the first four miles was 31.03 knots, equivalent to 36¼ miles per hour. The speed for the three hours continuous steaming was 30.15 knots.

OFFICIAL STEAM TRIALS DURING 1897 OF TORPEDO-BOAT DESTROYERS.

Ship.	Builder and engines.	Description of trial.	Indicated horse-power (three hours).	Speed (three hours).	Coal per indicated horse power per hour (when measured).
Quail	Laird	Speed.	6,049 *	30.104*	
Thrasher		Speed.	6,003 †	30.031†	
Earnest		Coal con.	6,266	30.047	2.41
Earnest		Speed.	5 931	30.137	
Griffon		Coal con.	6,268	30.019	2.53
Griffon		Speed.	6,081	30.111	
Panther		Coal con.	6,606	30 142	2.43
Panther		Speed	6,488	30 138	
Fame	Thornycroft	Coal con.	5,912	30.155	2.595
Fame		Speed.	5.852	30 168	
Foam		Coal con.	5 846	30 093	2.205
Foam		Speed.	5,654	30.184	
Mallard		Coal con.	5.746	30 201	2.08
Mallard		Speed.	5,905	30.115	
Star	Palmer	Coal con.	6,197	30.103	2.64
Whiting		Coal con.	6,254	30 167	2.76
Whiting		Speed.	6,315	30 209	
Bat		Coal con.	6,209	30 229	2.59
Bat		Speed.	6,199	30 129	
Crane		Coal con.	6,428	30 138	
Crane		Speed.	6,267	30.347	
Chamois		Coal con.	6,265	30.396	2.42
Chamois		Speed.	6,339	30.221	
Osprey	Fairfield	Coal con.	6,588	30 674	2.58
		Speed.	6,412	30.427	
Zebra	Thames / Maudslay	Speed.	4,816 ‡	27.003‡	

* Consumption trial, December 11, 1896. † Consumption trial, December 14, 1896.
‡ 27-knot boat.

Name of ship.	Type.	Shipbuilder.	Makers of Machinery.	Coal consumption trial 30 hours.			Natural draft.		Full power.	
				Indicated horse power.	Speed.	Coal per indicated horse power per hour.	Indicated horse power.	Speed.	Indicated horse power.	Speed.
					knots.	*pounds.*				
Jupiter.....	First-class battleship	Clydebank Company	Clydebank Engineering and Shipbuilding Company (Thomson)	6,198	14.1	1.51	10 248	15.8	12,475	18 4
Mars.....	Ditto	Laird	Laird	6,039	14.4	1.93 (Coal small at times.)	10,209	15.96	12,483	17.7
Hannibal.....	Ditto	Pembroke Dockyard	Harland and Wolff	6,124	14 6	1.78	10,357	16.3	12,138	17.6
Cæsar.....	Ditto	Portsmouth Dockyard	Maudslay	6 309	14.8	1 93	10,638	16.7	12,653	18.7
Terrible.....	First-class cruiser	Clydebank Company	J. and J. Thomson (Clydebank)	18,500	20.96	1.71	25,648 22,370	22.41	...	...
Doris.....	Second-class cruiser	N. C. and A. Company	N. C. and A. Company (Vickers)	4,933	16.5	1.47	8,425*	19.1	9,878*	19.7
Isis.....	Ditto	London and Glasgow Company	London and Glasgow Company	4.925	17.5	1.6	8,208	19.8	9.840	20 1
Arrogant.....	Ditto	Devonport Dockyard	Earle's Company	7,624	17.8	2 1	10,290	19.6	...	...
Illustrious.....	First-class battleship	Chatham Dockyard	Penn	6,155	14.5	1.77	...	...	...	...

*N. D. and F. D. trials in 1896.

The above list is exclusive of torpedo-boat destroyers, tugs, shallow-draught steamers and other small craft.

Wolf.—On January 7th H. M. S. *Wolf* went out for her full-power coal-consumption trial on the Clyde in the presence of the Admiralty representatives. Six runs, as usual, were made on the measured mile, with the following results:

	Steam.	*Time.* *min.*	*sec.*	*Speed.*
First mile	218	2	1⅛	29 57
Second mile	218	1	58⅜	30 41
Third mile	223	1	59¼	30.05
Fourth mile	224	1	57⅝	30 66
Fifth mile	224	1	59⅜	30.15
Sixth mile	224	1	57⅝	30.66

The mean speed was equal to 30.31 knots for the mile and 30.11 knots for the three hours' continuous steaming. The trial was made during somewhat boisterous and squally weather.

Diadem.—[Reprinted from "Engineering."]—The steam trials of H.M.S. *Diadem* are specially interesting, not only because she is the first of a class of which eight are now under construction, but also in view of the fact that here, for the first time afloat, the new arrangement of the Belleville water-tube boiler, with economizer in the uptake, is being tried. Thus thirty boilers have been provided to give 16,500 indicated horse power, without any pressing, and with a marked saving in weight as compared with the old cylindrical type, but it was intended to ascertain the effect of a modified measure of forced draft on a trial with only twenty-four out of the thirty boilers in use. The aim, of course, is to realize the full power with four-fifths of the boiler weight. Again there was a trial at cruising speed, developing about 12,500 indicated horse power with the twenty-four boilers, at the same time ascertaining the coal consumption.

The *Diadem* resembles the *Powerful* and *Terrible* in all respects, although costing less—£570,000 or so, instead of £725,000. She is smaller, being 435 feet long and 69 feet beam, as compared with 500 feet long and 71 feet beam, and, one aim being to enable her to pass through the Suez Canal, she is of 25 feet 3 inches draught and 11,000 tons displacement, against 27 feet draught and 14,200 tons. Her protection and armament does not differ materially

from the bigger ships, consisting of coal along either side, and an armor deck of 4 inches in thickness. Instead of having one 9.2-inch 22-ton breech loader, mounted at bow and stern to fire in line with the keel, there are in the same positions a pair of 6-inch quick-firers, with shields, and what little they lack in effective penetration at close range they make up for in rapidity of fire. In addition, there are four other weapons of the same caliber firing ahead and four astern, with four on the broadside, all in armored casemates, besides a splendid installation of smaller guns. But the part of most interest for the moment is the machinery.

The engines have four cylinders, working with three stages of expansion, and the ratio of the volume of the high to low pressure is 1 to 7.1, approximate to the practice in the merchant service, notwithstanding that the vessels of the latter work always at full power, while naval engines work oftenest at low power, but must have high power for emergency, so that an economical mean must be struck.

The designed steam pressure at the boilers is 300 pounds, at the engines, 250 pounds, and the high pressure cylinder is 34 inches in diameter, the intermediate 55½ inches, and the two low pressures each 64 inches, the stroke being 48 inches. The high pressure and intermediate cylinders are placed as close together as is possible, although they are separate castings, the piston valves for each being at the forward and after ends, respectively, and, similarly, the two low pressures are close together, without any valve separating them. Double ported slide valves are used in the latter cases. This arrangement of the cylinders, of course, reduces the tendency to vibration. The piston valves are balanced in themselves to take up the weight of the parts, and ordinary relief rings are used on the flat slide valves.

The framing differs from the *Powerful* and *Terrible* in that the front supports are forged steel columns, with cast iron A columns at the back, the sole plate being cast steel. The cranks are opposite in the case of the forward pair and also in the case of the after pair, and each pair is placed at right angles to the other. The crank and thrust shafts are 17½ inches in diameter, with a 9-inch hole, as is also that part of the propeller shaft which is outboard, while the

line shaft is 16¼ inches in diameter, with a 9-inch hole. The propeller has three blades, the diameter being 19 feet 6 inches, with a pitch of 22 feet 10⅜ inches in the case of the starboard, and of 22 feet 11½ inches in the case of the port screw. The blade area in each instance is 58 square feet. The thrust block area is 2,000 square inches.

The engine room is well arranged, with a fine, roomy starting platform, due, in some measure to Weir's feed pumps and the Belleville steam separator being relegated to the stokeholds, while the thrust blocks are within the engine room. The condenser is at the back, but separate from the engine, the cooling surface being 17,500 square feet for both engines. The air pump and a small bilge pump are worked from the main engines. There is a discharge into the hot well, from which the water is pumped through filters into a feed tank, whence Weir's pumps deal with it. These latter work against a pressure of 600 pounds, and arrangements are made for relieving any excess of pressure.

The economizer type of Belleville boiler has already been described in "Engineering," but it may be said that the system involves the dividing of the heating surface between the usual generator with 4½-inch tubes and an economizer with 2¾-inch tubes, the latter placed above the former, but sufficiently removed to leave a space to constitute a combustion chamber, into which, as well as into the main furnace, air is injected through a series of nozzles, so that in this chamber unconsumed gases are supplied with the air necessary for their effectual combustion.

The efficiency of the system will be more effectually tested when the boilers are "pressed;" but it may be said here that tests made by Admiralty officials with boilers on land showed that when burning 24 pounds of coal per square foot of grate, the feed water in passing through the economizer was raised in temperature from 68 degrees to 215 degrees, and when burning 37 pounds of coal, from 68 degrees to 230 degrees, the decrease of temperature in the gases being from, respectively, 1,112 degrees to 518 degrees, and from 1,560 degrees to 750 degrees. Certainly at the first trial the uptakes and boiler casings were kept cool, while there was an absence of smoke, and especially of ashes, from the funnel.

The thirty boilers, all single-ended, have a grate area of 1,460 square feet and a heating surface of 40,550 square feet, of which 29,600 square feet are in the generators and 10,950 square feet in the economizers. Originally, when the boilers were without economizers, the heating surface for the same grate area was to have been 45,915 square feet.

The first trial occurred on January 19 and 20, and was at one-fifth the full power, or 3,300 indicated horse power—a somewhat arduous condition, so far as economy is concerned. The mean consumption was 2.18 pounds per indicated horse power per hour, including coal for all auxiliary purposes, which may seem high to the engineer accustomed to run his engine at nearly full power, which is also a power intended by the designer as the most economical. But, as has been pointed out incidentally, the economical power in the naval service is probably only half of the maximum; so that, when the engines are run at full speed with very high steam pressures, all the power can not be utilized before the steam passes to the condenser, and, similarly, at very low powers the reverse holds good, much loss being due to radiation. This was probably the case with the *Diadem*. In the case of the *Powerful*, with a less coal consumption it is just possible that the loss was not so great, owing to the power arranged for in the low-pressure cylinders being much less. That it is not altogether due to the boilers is shown by the fact that the cruiser *Venus*, the only ship with cylindrical boilers tried at one-fifth of her full power, then required 2.9 pounds of coal per horse power hour.

Again, there were several engines running and using almost as much steam as if the main engines were developing full power. The steering engine, on the high-pressure system, with neither lap nor lead on the valve slides, owing to the necessity for quick action in maneuvering, uses a large amount of steam. A 600-ampère electric engine was running throughout the trial, with sanitary and bilge pumps, and other auxiliaries in use frequently, so that a large amount of the coal was used in running these, and the loss in their case is the greater, since most of them have only one stage of expansion—a few of them two only. This question is engaging the attention of engineers using high initial pressures,

and in future the practice will be more largely adopted of utilizing the steam for auxiliaries in feed heaters, instead of passing the steam, with much of its power still latent, into the auxiliary condenser. In some cases in the merchant service, it is passed into the receiver of the low-pressure cylinders, but the necessity for smart maneuvering in action requires that, in the Navy, the steam service of the main engines should not be interfered with in any such way; thus the simpler system of feed heaters is preferred in the Navy.

As to the results of the thirty hours', 3,300 indicated-horse-power, coal-consumption trial, we give the means in the Table below.

REPORT OF THIRTY HOURS' COAL CONSUMPTION STEAM TRIAL OF H.M.S. *DIADEM* IN THE ENGLISH CHANNEL.

		Forward.	*Aft.*
Draught of water, feet and inches		24–6	26–6
Steam in boilers, pounds		265	
		Starboard.	*Port.*
Vacuum, inches		27.6	26.6
Revolutions per minute		67.2	67.2
Mean pressure,	High, pounds	30.51	35 89
	Intermediate, pounds	12.14	8.72
	Forward low, pounds	7.36	6.85
	Aft low, pounds	7.60	8.14
Indicated horse power,	High	437	482
	Intermediate	478	344
	Forward low	386	363
	Aft low	398	427
Total indicated horse power		1,699	1,616
Collective indicated horse power		3,315	

The boilers worked admirably; the only point worth mentioning is that one or two of the fusible plugs blew out, but it only served to show the comparative safety of the boiler, for no trouble resulted. The plugs, which are of lead, are in the boxes into which the tubes of the elements are screwed, and are to obviate too high a temperature in the event of the feed apparatus failing. The engines worked splendidly, and, although no systematic attempt had been made at balancing, the arrangement we have described reduced vibration on the trial to the irreducible minimum.

The weather was most favorable, and early on the morning of January 21st four runs were made over the measured mile at Stokes Bay. The wind was of force 4, and was with the ship in the first and third run; but then a ½-knot tide was running against the ship. As the cruiser had left on the previous day with a mean draught of 25 feet 6 inches, having on board 1,780 tons of coal, with sufficient water to exceed the designed displacement, she was at the time of these measured mile runs, if anything, over her designed draught and displacement.

MEASURED MILE RUNS AT ONE-FIFTH POWER.

	First run.	Second run.	Third run.	Fourth run.
Mean vacuum, inches	27	27	27.25	27
Mean revolutions	67	69.9	66.1	67.8
Port engine, I.H.P.	1,658	1,701	1,567	1,617
Starboard engine, I.H.P.	1,627	1,749	1,534	1,527
Total	3,285	3,450	3,101	3,144
Speed, knots	13.168	12 00	13.667	11.92

The mean of mean speeds was 12.74 knots.

On board the vessel during the trial were the following officials: Sir A. John Durston, K. C. B., Engineer-in-Chief of the Navy; Mr. H. J. Oram, chief inspector of machinery, Melrose; Mr. E. R. Vine, Portsmouth Dockyard; Mr. H. J. Bakewell and Mr. E. Gaudin; Staff Engineer Rashbrooke, engineer of the *Diadem*. Mr. Alex. Gracie, engineering manager, represented the Fairfield Company, who built and engined the ship; and Mr. A. Sharer was also present from the Fairfield Works.

The *Diadem* completed on the evening of January 22d, at sunset, her second official trial, which was of thirty hours' duration, at about 80 per cent. of her full power—12,500 indicated horse power—with very satisfactory results. Here more distinctly than on the preceding trial was the efficiency of the new arrangement of boiler established, for the coal consumption worked out at a mean of 1.59 pounds per indicated horse power hour. This was for twenty-four hours—the usual practice being to exclude the first and last hours, so as to eliminate irregularities consequent

on the beginning and terminating of the trial; but, as it was, the mean for all thirty hours was 1.61 pounds.

This, it must be accepted, is very satisfactory; but it would have been still more so had it not been for the frequency with which the fusible plugs blew out. This is the first occasion of a trial at 280 pounds to 300 pounds boiler pressure, and it was found that the method of fitting the plugs was hardly as satisfactory as could be desired. The plugs were cast, probably rolled metal will be better; and it is under contemplation to adopt some system introducing modification to obviate the blowing out. Meanwhile the 480 plugs in the *Diadem* have been renewed, and their inside edges are being hammered up to prevent them, if possible, blowing out at subsequent trials, while, at the same time, their use as fusible plugs would not be interfered with. The effect of the plugs failing was the loss not only of much steam, but during the run some 67 tons of water had to be made by the distillers, and this quantity, it will be recognized, is abnormal. It is probable that some considerable part of the loss of water, however, may be attributed to a leaky joint on the delivery from one of the main feed pumps. This was not discovered till fairly late in the trial, and was then remedied by using an auxiliary instead of this main feed pump.

Again, with the economizer and its combustion chamber there was more latitude in the thickness of fire, without risk of incomplete combustion; but, at the same time, some regularity was observed in stoking. There was little smoke, no live sparks, and generally the boilers worked satisfactorily. No air was injected into the combustion chamber, and the flame there was intermittent. In the first thirty hours' trial, at 3,300 indicated horse power, such air supply was tried but discontinued, being found unnecessary. The chamber, it may be said, is divided by a baffle-plate which brings the gases to the front at the bottom and forces them to impinge on the whole length of the lowest row of tubes in the economizer. The injected air mixes with the gases at the middle of the combustion chamber. There are seven pairs of tubes in the elements in the generator and a similar number in the economizer; but the latter, in ad-

dition to being smaller in diameter, are shorter; so that in width the four economizers athwartship occupy about sixty per cent. of the width given to the four generators, and the smoke box or uptake is so formed that the funnel comes right down on the top of the economizers. On the full-power trial the air supply was constant, with favorable results. Not only was there more latitude in stoking, but the temperature in the stokeholds was lower than in the other ships, no fans being used, and, as a rule, the ashpit doors were only slightly open. There was a plentiful supply of steam, effort being made to keep it at 280 pounds, and it only varied about 3 pounds throughout the 30 hours.

The jackets were not used on the high-pressure cylinders. This course was decided upon after an examination of the inside of the cylinders on the termination of the previous 30 hours' trial, which showed that the steam was especially dry, and in the other cylinders the jacket pressures were arranged to equal those in the receivers.

A point of interest, although of little importance in connection with the working of the engines, was that the intermediate cylinder of the port engine gave much less power than the high-pressure cylinder, due largely to the fact that a slight alteration had to be made to the valve to this cylinder prior to the trials, and probably it was not exactly of the same adjustment as originally. But before the trial had gone far, a slight alteration in the intermediate independent linking put this right, and for the greater part of the time the engines ran without the links or the regulating valves being touched. The cuts-off of the high-pressure cylinders were approximately 58 per cent. of the stroke in the case of the port engine, and 60 per cent in the case of the starboard. With the exceptions we have indicated, the high-pressure and intermediate cylinders worked uniformly at the same power. In some cases the difference was as low as ten indicated horse power, and it was never an important percentage of the power except once or twice in the port engine. Similarly, with the two low-pressure cylinders there was even greater uniformity, the variation being about 3 per cent. at most. The advantage, of course, of the equality of power is in reducing the vibra-

tion of the ship. Generally the vessel was very steady, and, apparently, it was only at 110 to 112 revolutions that the synchronizing period of ship and engine was reached. Even then the vibration was but slight. In the *Powerful* and *Terrible* this was 93 revolutions. The port engine, as a rule, gave rather less power, partly due to the valve setting already referred to, and also possibly to a difference in the pitch of the screw.

REPORT OF THIRTY HOURS' STEAM TRIAL OF H.M.S. *DIADEM*, IN THE ENGLISH CHANNEL, JANUARY 21 AND 22.

		Forward.	*Aft.*
Draught of water, feet and inches		24–4	26–5
Steam in boilers		280	
		Starboard.	*Port.*
Vacuum, inches		27	26.5
Revolutions per minute		107.8	107.4
Mean pressure	High, pounds	79.65	78.05
	Intermediate, pounds	29.54	26.65
	Forward low, pounds	16.28	16.41
	Aft low, pounds	16.40	16.34
Indicated horse-power	High	1,890	1,843
	Intermediate	1,868	1,678
	Forward low	1,371	1,375
	Aft low	1,380	1,371
Total indicated horse power		6,509	6,267
Collective indicated horse power		12,776	
Mean air pressure		*nil*	
Speed of vessel, mean of three deep-sea runs		19.79	
Coal consumption per indicated horse power, pounds		1.59	

It is scarcely worth while to refer to the variations in the coal consumption, for the rate recorded hourly depends on the amount taken out of the bunkers, and thus the amount on the stokehold plates at the end of the hour varied; but if we except the first and second hours—respectively 2.5 pounds and 1.4 pounds, we find that only twice did the record show 1.7 pounds; as a matter of fact 1.5 pounds and 1.6 pounds were most frequently recorded. The mean as we have said, was 1.59 pounds, and seldom has the rate for ordinary boilers been so low. There is every prospect of a still lower rate in subsequent trials, when the cause of the loss in steam and water to which we have referred has been overcome.

On the morning of January 22d, three runs were made over the deep-sea course between Dodman Point and Rame Head, cross bearings being, as usual, taken, to determine the distance steamed. The weather was most suitable for such a trial of speed. There was no wind and the sea was calm. The first run was made from Dodman Point to Rame Head, with a slight current against the ship, and the speed was 19.20 knots; on the second run it was 20.35 knots, and on the third, 19.25 knots. The mean of means was thus:

Speed, knots	19.79
Revolutions per minute	109.8
Power, I.H.P.	13,000

We give on the next page the results of the engine performance during these three runs, and these may be taken as fairly representative of the great majority of the thirty hours. The ship during the thirty hours' run steamed right down the English Channel as far as the Scilly Isles, and afterwards cruised in the vicinity of Plymouth. The log, it may be added, showed a speed of 19.53 knots. There was fog in some places, in the eastern parts of the Channel; but to the west the wind varied between force 2 and 3. The draught of the ship was, forward, 24 feet 4 inches, aft, 26 feet 5 inches, so that she was down to full-load displacement when her speed was realized.

It may be mentioned that the anchor gear on board the *Diadem* has been subjected to interesting trials. The bower anchors are $5\frac{1}{2}$ tons each, and the cable $2\frac{3}{8}$ inches; the stern anchor cable is $1\frac{5}{8}$ inches, and the cat chain $1\frac{1}{4}$ inches. The anchor gear was required to heave in either one or both bower chains at the rate of 75 feet in three minutes; this was done in both cases at the rate of 75 feet in two minutes fifteen seconds. The slack of the cat chain was run in at the rate of 40 feet in fifty seconds, and the taut of the cat chain, with the weight of the anchor on it, at the rate of 20 feet in forty-four seconds; everything worked satisfactorily. The capstan engines and gear, with riding bitts, etc., both forward and aft, were made by the Messrs. Napier Brothers, Limited, of Glasgow, and are very similar in construction to the gears fitted by the same firm in the *Powerful* and *Terrible* and others of H.M.

ships, and illustrated in our issue of August 23, 1895. The forward capstan engines have cylinders 13½ inches in diameter and 10 inches stroke, and are geared to the capstans in such a manner that each of the three cable holders, as well as the capstan on the forecastle deck, may be worked independently or in conjunction with any of the others, veering or heaving as may be required. The wormwheels, as well as the spur and bevel gearing, have machine-cut teeth, as is the usual practice in all gears fitted in H.M. ships. A feature in the gear is the powerful brakes, one for each cable holder. These brakes are entirely separate from the hoisting purchases, and are powerful enough to hold the cables against the greatest stress that may be brought upon them. At the same time, they give control over the cables, and can be handled by the attendant with ease, veering or stopping the cables instantly as required.

H.M.S. *DIADEM'S* SPEED TRIALS ON THE DEEP-SEA COURSE, JANUARY 22, 1898.

		First run. W. to E.		Second run. E. to W.		Third run. W. to E.	
		Starboard.	Port.	Starboard.	Port.	Starboard.	Port.
Mean steam in boilers, pounds		280	...	280	...	280	...
Mean steam at engines, pounds		265	273	266	270	280	268
Mean air pressure in stokeholds		...	...	...	...	...	...
Mean cut off in high-pressure cylinder, per cent		60	58	60	58	60	58
Mean vacuum, inches		27	26	27	26.5	27.25	26.25
Mean revolutions		109.5	110.0	109 0	109.4	111.7	110.6
Mean pressure in cylinders,	High, pounds	77.7	75.2	79.6	75.4	81.2	77.2
	Intermediate, pounds	30.4	25.9	29.6	26.6	29.9	26.4
	Low forward, pounds	16.3	15.9	16.3	16.4	16.6	15 8
	Low aft, pounds	16.6	17.1	16.5	16 5	16.7	16.4
I.H.P	High	1,872	1,820	1.909	1,815	1,995	1,878
	Intermediate	1,951	1.670	1,891	1,705	1.957	1,711
	Low forward	1,392	1,364	1,386	1,399	1,446	1,363
	Low aft	1,418	1,467	1,403	1,408	1,455	1,415
Total I.H.P		6,633	6,321	6,589	6,327	6,853	6,367
Gross total I.H.P		12.954		12.916		13,220	

Speed, first run, knots	19.20
Speed, second run, knots	20.35
Speed, third run, knots	19.25

The vessel went out again on January 26th for a full-power trial, returning to Portsmouth late in the evening. We give in a table the mean results and the speed got on the three runs on the deep sea course.

REPORT OF EIGHT HOURS' STEAM TRIAL H. M. S. *DIADEM*, IN THE ENGLISH CHANNEL, JANUARY 26, 1898.

		Forward.	*Aft.*
Draught of water, feet and inches		24.3	26.4
Steam in boilers, pounds		291	
		Starboard.	*Port.*
Vacuum, inches		27	26.5
Revolutions per minute		119.3	118.9
Mean pressure,	High, pounds	91.3	84.63
	Intermediate, pounds	34.73	32.72
	Forward low, pounds	21.81	20.22
	Aft low, pounds	21.76	20.80
		Starboard.	*Port.*
Indicated horse power,	High	2,398	2,213
	Intermediate	2,431	2,281
	Forward low	2,032	1,860
	Aft low	2,027	1,946
Total indicated horse power		8,888	8,300
Collective indicated horse power		17,188	
Mean air pressure		*nil*	
Speed of vessel, mean of three deep sea runs		20.6	
Coal consumption per indicated horse power per hour		1.77	

RESULTS OF THREE SPEED RUNS ON DEEP SEA COURSE.

	Revolutions.	*Power.*	*Speed.*
First run	118.9	17,155	20.72
Second run	119.	17,053	20.72
Third run	119.1	17,053	20.20
Mean of means	119.	17,079	20.6

The trial of January 29th was for four hours, to determine what power could be maintained with twenty-four out of the thirty boilers; or, in other words, with 78 per cent. of the heating surface in use, the intention being to get 1 indicated horse power for each 2 square feet of heating surface. The latter trial was as successful as that of January 26th, when the power was equal to 1 horse power per 2.36 square feet of the total heating surface; but the higher result was realized with a modified measure of forced draft, the water gauges in the stokeholds

showing a mean pressure of 0.3 inch. This, of course, is small; indeed, in times past, anything under 0.5 inch was accepted as natural draft conditions; but, in recent years, with the Belleville boilers, it has been the custom, and a most commendable one, to design the boilers to realize the maximum, or, more properly speaking, the emergency power, with open stokeholds. This emergency power to be resorted to for a spurt, is, in the case of the *Diadem*, 16,500 indicated horse power, giving 20½ knots speed at full displacement, while her continuous steaming, or for all ordinary purposes, her full power is 12,500 indicated horse power, giving about 19¾ knots. No steamer has more easily realized this latter power than did the *Diadem* on January 21 and 22. The stokehold was open, no fans were used, 14.33 pounds of coal were burned per square foot of grate for thirty hours, giving 8.87 indicated horse power per square foot, while the coal consumption for twenty-four continuous hours was at the rate of 1.59 pounds per indicated horse power per hour. We have previously referred to the blowing out of fusible plugs simply to relieve the monotony of a pronounced success.

On the two maximum or emergency-power trials there was no such incident to afford any shade of contrast, for the means taken in dealing with the plugs were effective, and everything else went well. As shown in the Table, the mean power with all the boilers in use was 17,188 indicated horse power; but before the links were set for the trial, over 18,931 indicated horse power was developed, and throughout the eight hours no difficulty was experienced in the stokeholds. The draft by the four funnels, which are 90 feet high above the grate bars, and 8 feet 6 inches internal and 10 feet 6 inches external diameter, was sufficient, and the stokeholds were particularly free from dust, while the temperature was lower than in any ship for many years.

The coal consumption, too, was very moderate, being only 1.77 pounds per indicated horse power per hour for eight hours continuous steaming, a result which is seldom equaled even in the merchant service, where the data are collected without regard to that scrupulous accuracy which is characteristic of all Admiralty trials. Hourly or half-hourly results taken by a staff of sixty

recorders are very different things from diagrams taken once a day by the ship's officers on which to base consumption results. The coal burned per square foot of grate area was 21.14 pounds for eight hours, and the power realized 11.93 indicated horse power per square foot.

It will thus be seen that the extra 4,300 indicated horse power realized on the emergency-power trial necessitated extra pressing to the extent of burning 47.5 per cent. more coal on the grate, while the power was 34.4 per cent. greater, and thus each indicated horse power was got for 2.36 square feet of heating surface, instead of for 3.17 square feet. But withal, the steaming, even for this emergency power, was so easy that there is no reason why it could not be maintained for a much longer period by the ship's company than eight hours, and Sir John Durston is certainly to be congratulated on the result. The power, for instance, for three consecutive hours was 17,061, 17,072 and 17,015; and two runs in opposite directions over a 22.8-knot course differed in their duration by only two seconds. There was very little variation, too, between the powers in the high-pressure and intermediate cylinders, and between the two low-pressure cylinders.

The first of several experimental cruises for the securing of data for use in connection with future designs was run on January 29, the aim being to determine how much could be done with three of the four batteries of boilers in the ship, getting as nearly as possible one indicated horse power per 2 square feet of heating surface. And here it may be noted that the water-tube boiler has a great advantage in the convenience with which it can be adapted to the form of a ship. Sir William White's cruisers are characteristic for their fine form, by which high speeds can be realized without abnormal expenditure of power; and, consequently, the boiler rooms are of decreasing width as they extend forward. It is only necessary to vary the number of elements to suit this decreasing beam of ship, and thus it follows that in the forward stokehold in the *Diadem* there is twenty-two per cent. of the boiler power, in the next twenty-four per cent., and in each of the two after compartments twenty-seven per cent.

In this first experimental trial, therefore, the six boilers in the forward stokehold were not used, so that there was only seventy-eight per cent. of the heating surface available, or 31,660 square feet with 1,124 square feet of grate. The extent of forcing is shown by the air pressure, 0.3 inch, by the fact that the six fans—two in each boiler room—of 7 feet 6 inches in diameter, were run at a mean of 227 revolutions per minute, and by the vacuum in the smoke box being 0.45 inch. The increased pressure, with the steam required by the fan engines, which are of the simple type, taking steam at full stroke, necessarily involved a higher rate of coal consumption; but, withal, it was only 1.95 pounds per indicated horse power per hour, including the steam for all auxiliaries. The coal burned per square foot of grate area was 27.52 pounds, thirty per cent. more than with all the boilers in use under ordinary funnel draft, while the power was 18.3 per cent. higher per square foot.

The aim of the trial—to secure an indicated horse power per 2 square feet of heating surface—was satisfactorily realized, the ratio being one horse power to 1.99 square feet. The result was attained with comparative ease, and it may almost be said that with open stokeholds and funnel draft, 15,000 indicated horse power could be reached with, of course, a higher economy. This would give one indicated horse power per 2.1 square feet of heating surface, whereas in the later cruisers, with cylindrical boilers, 2.5 square feet of heating surface has been allowed per indicated horse power. The air blown through the nozzles into the furnaces and into the combustion chambers under the economizers, was at an average pressure of 11.2 pounds.

The engines worked well. In the full power trial with all the boilers, when 17,188 indicated horse power was the mean, the cut-off was at 67.3 per cent. of the stroke in the starboard, and 66.3 per cent. in the port engine; while in the further trial, with 78 per cent. of the boiler power, when 15,861 indicated horse power was realized, the cut-off was a trifle earlier. The engines worked very steadily at about 116 revolutions, with a plentiful supply of steam, and, as in the 12,500 indicated horse power trial, no steam was passed through the high pressure cylinder jacket.

REPORT OF FOUR HOURS' STEAM TRIAL H.M.S. *DIADEM* IN THE ENGLISH CHANNEL, ON JANUARY 29, 1898, WITH 78 PER CENT. OF BOILER POWER.

		Forward	*Aft.*
Draught of water, feet and inches		24–3	26–6
Steam in boilers, pounds		291	
		Starboard.	*Port.*
Vacuum, inches		27.2	26.3
Revolutions per minute		116.2	116.4
Mean pressure,	High, pounds	85.73	82.63
	Intermediate, pounds	34.36	33.16
	Forward low, pounds	19.97	18 02
	Aft low, pounds	20.13	18.50
Indicated horse power,	High	2,191	2,116
	Intermediate	2,340	2,262
	Forward low	1,811	1,636
	Aft low	1,826	1,679
Total indicated horse power		8,168	7,693
Collective indicated horse power		15,861	
Mean air pressure, inch		0.3	
Coal consumption per indicated horse power per hour, pounds,		1.95	

The preceding Table gives the mean results of the four hours, and a comparison with the corresponding table for the eight hours' trial on January 26th, will show that the reduction in power may be said to have been uniformly divided. The power might have been greater; at one time it was 16,500 indicated horse power for 117.4 revolutions, and two other returns showed over 16,000 indicated horse power; but the aim was to see what power could be got without unduly pressing the boilers, and, as said, with conditions generally favorable, 15,000 indicated horse power, or 1 horse power per 2.1 square feet of heating surface can easily be got with open stokeholds. The forced draft limit depends entirely on expediency: 0.3 inch may not be high for emergency; but it must ever be remembered that when that maximum is required, even for a short spurt, it is wanted badly, and gain will undoubtedly accrue if it can be realized without undue effort, physical or mechanical.

At the conclusion of the four hours' trial on January 29th, the starting and reversing trials of the propelling engines were made. The gear is of the all-round navy type, and the starboard engine was brought to a dead stop in twenty seconds, the port engine

in eighteen seconds. From stop to full speed astern, the time taken was nine seconds by the starboard and seven seconds by the port engines, while from full speed astern to full speed ahead, the time was fifteen seconds for the starboard and eighteen seconds for the port engines. With the ordinary hand gear the port engine was brought to a dead stop in thirty seconds, to full speed astern in five seconds, and from full astern to speed ahead in thirty-one seconds.

The steering gear was next tried. Messrs. Napier Brothers, Limited, Glasgow, supplied the engines, and Messrs. Harfield the gear, which is of the compensating type now usual in the Navy. The steam steering engines, as well as the gear, are made in duplicate, as is now the practice in all the large vessels of Her Majesty's Navy. One set of engines is fitted on the bulkheads of the starboard engine room, the other in the port engine room, so that, like most of the other mechanism in the ship, they are under the eye of the engineer. The two engines can be coupled together by a shaft passing through a water-tight stuffing box in the longitudinal bulkhead in such a manner that either engine or both may be used for steering the ship. The cylinders are 12 inches diameter and 11 inches stroke, and are designed so that one engine is capable of steering the ship easily with a steam pressure of 200 pounds per square inch. The full boiler pressure is 300 pounds per square inch. The engines are controlled from any of the five steering positions in the ship; the length of controlling shafting is 750 feet, and the weight about 2 tons. Two of the steering positions are on the bridges, two below the protective deck, and one in the conning tower. The steering engine in the starboard engine room was tried first; and the time from amidships to hard-a-port (35 degrees) was eleven seconds, from port to starboard (70 degrees) seventeen seconds, back to port seventeen seconds, and from port to amidships (35 degrees) eight and one-half seconds. In the case of the port steering engine the times were from amidships to port (35 degrees) ten and one-half seconds, from port to starboard (70 degrees) eighteen seconds, back to port twenty seconds, and from port to amidships ten seconds.

FRANCE.

Naval Programme for 1898.

The French Naval Administration does not appear to be slackening in the activity which it has displayed for some time past. In the Government arsenals twenty-seven vessels are now in course of construction. At Cherbourg an expenditure of $1,200,000 will be made next year upon the ironclad *Henri IV.* An ironclad cruiser, known at present as the *C-4*, will be commenced next year, and an expenditure of $400,000 is to be made upon her during the twelve months. A further expenditure of $70,000 is to be made upon the second-class cruiser *Cassard*, which is now nearly completed. Expenditures of $240,000 and $250,000 respectively are proposed to be made in 1898 upon the torpedo-boat destroyers *Dunois* and *La Hire;* the first of these vessels, it should be noted, is already launched. Two first-class torpedo boats were ordered in April, 1897, to be laid down at Cherbourg, and it is proposed to expend $35,000 upon each of them next year. Finally, a submarine boat, to be named the *Morse*, is to be completed at Cherbourg next year; the expenditure proposed to be made upon her during the twelve months is $90,000.

Several ironclads are in hand at Brest. The *Charlemagne*, which is approaching completion, will involve an expenditure of $675,000 in 1898. Upon the *St. Louis* there will be an outlay of $1,000,000. The *Gueydon* cruiser, which was laid down in August, 1897, will call for an outlay of $760,000 next year. Another cruiser known at present as the *C-7*, will be commenced next year, and $400,000 will be devoted to her construction during the twelve months. The *Jurien de la Gravière*, a first-class station cruiser, will require an expenditure of $645,000; and for the *Décidée*, gunboat, which is to be laid down in the course of 1898, $150,000 will have to be provided.

A first-class station cruiser, known at present as the *D-3*, is to be commenced at Rochefort before the close of this year; the outlay proposed to be made upon her in 1898 is $320,000. Two cruisers are also in hand at Rochefort. The first of these—the *Lavoisier*—is now almost completed; the outlay proposed to be

made upon her next year is $85,000. The second is the *d'Estrées*, which has just been launched, and for which $300,000 will have to be provided in 1898. Another vessel now in progress at Rochefort is the *Kersaint*, a first-class despatch boat, upon which a final expenditure of $160,000 will have to be made next year. The last ship comprised in the Rochefort programme is the *Vaucluse*, a despatch boat, the construction of which has been suspended for several years, and upon which it is proposed to expend $19,000 in 1898.

Two ironclad cruisers are in hand at Toulon. Upon the first of these—the *Jeanne d'Arc*—an expenditure of $1,500,000 is proposed to be made next year. The second—the *Dupetit Thouars*—was laid down two months since; she will call for an outlay of $710,000 in 1898. The only remaining vessels in hand at Toulon are two first-class torpedo boats, Nos. *225* and *226*; each of these torpedo boats will absorb $35,000 next year. It will be seen that the total construction expenditure in the French Government arsenals in 1898 will be about $9,000,000.

So much for what is being done in the French arsenals. As regards French private establishments, they are now engaged upon one ironclad and five armor-plated cruisers. The ironclad is the *Massena*, which has been recently making trial trips near Brest. The five armor-plated cruisers are the *d'Entrecasteaux*, the *Montcalm*, the *C-8*, the *Dessaix* and the *Kléber*. The *d'Entrecasteaux* may be considered as terminated; an expenditure of $460,000 remains to be made, however, upon her in 1898. The *Montcalm* will involve an outlay next year of $690,000. The *C-8* will not be commenced until next year; the sum voted for her construction for the twelve months is $240,000. The *Dessaix* and the *Kléber* will each absorb next year $745,000. Private firms have also in hand two first-class station cruisers—the *Guichen*, which has just been launched, and upon which $965,000 is to be expended next year, and the *Chateaurenault*, which is also afloat, and which will absorb $940,000 in 1898. The *Guichen* will be ready for sea in August. Two second-class station cruisers are, further, in course of construction by private firms; these are the *Catinat*, which is now making trials at Cherbourg,

and which will only call for a final balance of $87,000 next year, and the *Protet*, which will be delivered by her builders next year, and which calls for an allocation of $430,000 during the twelve months.

A third-class station cruiser, to be named the *Infernet*, is in course of construction at Bordeaux; she will involve an outlay of $245,000, next year. The construction of eight squadron torpedo-boat destroyers will be entrusted to private firms next year; six of these vessels, the *Durandal*, the *Hallebarde*, the *Fauconneau*, the *Espingole*, the *Pique* and the *Epée*, are to be build at Havre; the remaining two, the *Framée* and the *Yatagan*, are to be put in hand at Nantes. All of these vessels are to be ready for sea by June, 1899, at latest. Six squadron torpedo boats are also being built by private firms; the first, the *Cyclone*, is to be delivered in February; she will involve an outlay next year of $60,000. The five other torpedo boats will only be commenced in the course of next year; the amount allocated for the construction of each of them during the twelve months is $30,000. No fewer than thirty-two first-class torpedo boats are being constructed for the French Navy by private firms; twenty-six of these are already in hand and six will be commenced in the course of 1898. The cost of three of these torpedo boats, known as *Nos. 206*, *207* and *208*, will be balanced off next year, but they will be delivered before January 1. As regards the remaining vessels of this class, *Nos. 209* to *227* will be delivered in the course of 1898, as well as *230* and *233*. The remaining vessels, as far as *235*, will be delivered in 1899. Six torpedo boats, which have still to be commenced, are known at present as the *P-55*, the *P-56*, the *P-57*, the *P-58*, the *P-59* and the *P-60*. A steam shallop has been completed by a private firm; a balance of $4,000 will be paid in respect to her next year.

Altogether eighty-five vessels are in the course of construction for the French Navy. Of these, twenty, which have not yet been commenced, will be put in hand in the course of next year. In the first category may be mentioned a first-class station-cruiser at Rochefort, three armor-plated cruisers, the *Montcalm*, the *Dessaix* and the *Kléber*, and the torpedo-boat destroyer *Yatagan*.

The second category includes an ironclad at Brest, an ironclad-cruiser at Cherbourg and another at Lorient, as well as an iron-clad-cruiser, five squadron torpedo-boat destroyers, and six first-class torpedo boats in private yards. The plans of the ironclad which is to be laid down at Brest have not yet been finally completed; the ship is, however, to have a displacement of 12,000 tons.

Of the six ironclad cruisers not yet commenced, four are of the first rank; these are known at present as the *C-4* and the *C-7*, which are to be built at Cherbourg and Lorient, respectively; and the *Montcalm* and the *C-8*, which are to be built in private yards. The two remaining vessels, the *Dessaix* and the *Kléber*, are second-class. The first four vessels will have a displacement of 9,517 tons each; and they will each be 443 feet 4 inches long by 64 feet 8 inches beam. These cruisers are to be fitted with three screws, and their prescribed maximum speed is to be 21 knots per hour; they are to have vertical triple-expansion engines working up to 19,600 horse power, and they will be supplied with steam from water-tube boilers. They will be able to carry sufficient coal to enable them to steam at the rate of 10 knots per hour for a distance of 10,300 miles, and 1,920 miles when their engines are working at their utmost speed. They will each carry thirty-four guns and two submarine torpedo tubes.

The second-class cruisers will have a displacement of 7,700 tons each; they will be 433 feet 4 inches long, and 59 feet 4 inches beam. Their vertical triple-expansion engines will work up to 17,100 horse power, and will receive steam from water-tube boilers; they will be fitted with three screws, and their prescribed maximum speed is to be not less than 21 knots per hour. They will be enabled to run 8,800 miles when steaming 10 knots per hour, and 1,650 miles when their engines are working at their utmost speed. They will each carry twenty-six rapid-firing guns and two above-water torpedo tubes.

The plans of the first-class station cruiser are in course of preparation. The displacement provided for is 5,000 tons; the maximum speed is to be 21 knots per hour, and the armament is

to be similar to that of the *Jurien de la Gravière*, viz: twenty-four guns, all rapid-firing.

Plans for five of the squadron torpedo boats are still under consideration; they are each, however, to have a displacement of 150 tons. The six first-class torpedo boats will have a displacement of 84 tons; they will be 123 feet 4 inches long by 15 feet 4 inches beam; their maximum speed is to be 23.5 knots per hour; they will each carry two rapid-firing guns and two submarine torpedo tubes.—"Engineering."

Du Chayla, is of the *Bugeaud* type slightly enlarged, and was launched at Cherbourg, on November 18, 1895. The principal dimensions are:

Length, between perpendiculars, feet,	325.6
Beam, feet,	44.9
Depth, feet,	29.8
Draught, aft, feet,	20.5
Draught, mean, feet,	19.0
Displacement, tons,	3,888
I.H.P., under forced draft,	9,370
Speed, knots,	19.25

The protective deck has inclined sides, 3.15 inches thick, and a flat top, 1.2 inches thick. The cofferdam along the water line is filled with cellulose.

The armament is the same as that of the *Bugeaud*, namely: six 6.3-inch and four 3.94-inch rapid-fire guns, several 1.85 and 1.46-inch guns and two torpedo tubes.

There will be twin-screw vertical triple-expansion engines and twenty d'Allest water-tube boilers placed in three compartments.

The coal capacity is about 600 tons. The complement will be 14 officers and 371 men. The total cost is estimated at $1,579,176.

Fauconneau.—A partial description of this torpedo-boat destroyer has already been given in the JOURNAL, Vol. IX, p. 610. The following description of this vessel and the other five of the class, *Espingole*, *Pique*, *Épée*, *Framée* and *Yatagan*, is taken from "Le Yacht." The principal dimensions are: length between perpendiculars, 195.5 feet; beam at water line, 17.22 feet; greatest

beam, 20.67 feet; draft of water aft under the propellers, 9.91 feet; displacement on trial, 311 tons; cruising displacement, 319 tons.

The hull will be divided into ten water-tight compartments by nine bulkheads. The first compartment at the bow is empty; the second and third will be occupied by the crew. The engines will occupy the middle of the vessel, that is to say, the fifth and sixth compartments, which do not communicate except by a water-tight door situated above the water line. The boilers, in two groups, will occupy the fourth and the seventh compartments. The eighth compartment is given up to the apartments of the officers, to which access is obtained by a ladder ending in an ante-chamber. The ward room is nicely furnished and has a room for one officer on each side as well as places for the captain and the second in command. Below these apartments a portion of the ammunition for the 47-millimeter rapid-fire guns will be placed. The petty officers will occupy the following apartment, which is next to the last.

Upon the forward part of the upper deck will be installed a pilot house containing the steering wheel with telemotor and the various voice tubes and other means of communication for the captain. From this pilot house to the stern extends a working platform supported by angle iron pillars. The galley is protected by a light roof and is on the deck just above the boilers.

The armament will consist of two torpedo tubes with central pivots, one amidships and the other at the stern. Besides the torpedo tubes, there will be one 65-millimeter rapid-fire gun placed upon the pilot house, and six 47-millimeter rapid-fire guns, three on each side, abaft the pilot house. There will be two signal masts 52 feet in height. There will be a 23-foot whale boat and three smaller boats.

The propelling machinery will consist of two vertical triple-expansion engines of a combined power of 5,700 horses, which are expected to give a speed of 26 knots. For 14 knots the horse power will be 800. There will be four Normand boilers working at a pressure of 225 pounds. They will have seamless drawn tubes, and the furnace and ash pit doors will be arranged to close automatically in the case of back draft or a bad steam

leak into the fire room. Although each group of one engine and two boilers is independent under normal conditions, arrangements will be made so that either or both engines can be run with any one of the four boilers. The bunkers will hold 37½ tons of coal, giving a radius of action of 2,300 knots at a speed of 10 knots, and 217 at the maximum 26 knots. The boats will be lighted by electricity from a single dynamo of 50 ampères and 80 volts.

HOLLAND.

Friesland.—The Fyenoord Shipbuilding and Engineering Works at Rotterdam, between October 18 and November 3, 1897, successfully carried out an exhaustive series of trials with the machinery and boilers of the Cruiser *Friesland*, one of three cruisers ordered by the Dutch Government in 1895.

The advantages in weight and space to be derived from the use of express water-tube boilers were so great that Mr. Beucker Andreae, Inspector of machinery to the Royal Dutch Navy, after careful study, decided to use two cylindrical boilers and eight express boilers of the Yarrow type, the two cylindrical boilers to be used for ordinary cruising purposes and the express boilers to be used for higher powers.

The two cylindrical boilers have 4,005 square feet of heating surface and 126 square feet of grate area, the eight water-tube boilers 16,140 and 322 square feet, the working pressure for all boilers being 200 pounds.

The feed is effected by four Weir's pumps, one in each engine room and one in each stokehold, with piping so arranged that each pump can draw from all tanks and fresh water compartments and can feed each of the ten boilers separately as may be required. The check valves are regulated by hand, and no automatic arrangements whatever have been used, and on no occasion during the prolonged trials was any difficulty experienced with feeding; in fact, after a little training the firemen much preferred the new boilers to the cylindrical ones on account of the convenience in firing.

The engines are the usual three-crank triple-expansion type with piston valves throughout. The high-pressure cylinders are

33 inches, the intermediate, 49 inches, and the low pressure, 74 inches diameter, with 39 inches stroke. All cylinders are steam jacketed. Columns, bedplates, pistons, cylinder covers, etc., are of cast steel, supplied by Messrs. Skoda, of Pilsen, in Bohemia. The shafting, from Krupp, is hollow throughout. Piston rods and valve spindles have United States Metallic packing. The propellers are of Delta metal, 13 feet 6 inches diameter and 16 feet pitch, starboard propeller being left handed and port propeller right handed. The usual auxiliary machinery is disposed in the engine room, including a large Hall's refrigerator for cooling ammunition compartments, provision stores, etc. Two dynamos in engine room supply the necessary current for electric lighting, search lights, and electric ammunition lifts by Krupp.

The main steam pipes are solid steel forgings, turned on the outside with solid flanges, and bored out, leaving ample metal to secure the required thickness. All T and L pieces are of gun metal, and the whole carefully designed with stuffing boxes and stay bolts to allow of expansion and contraction. This system of steel steam pipes without welds or rivets has given great satisfaction in the Dutch Navy.

The trials of machinery were carried out by Mr. Beucker Andreae and his staff, and are too extensive to be given in detail. The principal results were the following:

Date.	No. boilers at work.	Collective mean I.H.P.	Mean revolutions.	Open or closed stokehold.	Coal per I.H.P. per hour.	Auxiliary machinery included.
					pounds.	
19 Oct.	4 Yarrow	2,006	87.25	Open	6 hrs., 1 84	a
20 Oct.	All boilers	5.982	124.2	Open	4 hrs., 1.707	a & b
3 Nov.	All boilers	10,416	147.27	Closed	4 hrs., 1.727	a & b

NOTE.—Auxiliaries *a* are Weir's pumps, circulating pumps and fans; *b*, dynamo, steering-gear and duplex pump.

The mean vacuum on the full power trial was 24.75 inches, on the half power trials, 26.25 inches. The steam from the boilers was passed through a simple form of steam drier and the drain used to heat the feed water.

The engines worked without water upon any part and with the utmost regularity, the boilers supplying an abundance of steam, with a mean air pressure corresponding to 1¼ inches water column—the maximum pressure not exceeding 1½ inches, the contract allowing 2 inches. The vibration at the maximum power was so little that writing immediately above the propellers was quite practicable.

The total weight of engines and boilers does not exceed 600 tons; which shows the immense advantage in weight to be derived from the use of the Express boilers, besides it being possible to renew and repair these boilers without disturbing any part of the armored deck or of the ship proper.

These cruisers have the following dimensions:

Length on loadline, meters	93.
Breadth molded, meters	14.75
Draft upon trial, meters	5.40
Displacement, tons	3,900

The ships were designed by Mr. Loder, Director of Naval Construction and have been built specially for service in the Dutch Colonies.

JAPAN.

Kasagi.—The launch of this vessel at the Cramp shipyard on January 20th, is an event of some importance, as she is the first foreign warship launched in America since the Russian warship *Zabiaca*, in 1878, which was built by the same firm.

The dimensions of the *Kasagi* are: Length, 374.5 feet; breadth, 48.75 feet; depth, 30 feet; mean draught, 17 feet 9 inches; displacement at that draught, 4,900 tons. In the specifications she is classed as a protected cruiser of the second-class, and, like all vessels of her type, has no defensive armor, relying on her coal bunkers, which run 108 feet fore and aft of her amidship section, to protect her engines, which are entirely below the water line. Above these is a protective deck, having a maximum thickness of 4.5 inches on the slopes and 1.75 inches on the flat.

The motive power is supplied by two vertical, inverted, triple-expansion, four-cylinder engines, driving twin screws, and esti-

mated to develop, under forced draft, a mean speed of 22.5 knots per hour. The engines are of 17,000 horse power, and the boiler rooms contain twelve single-ended boilers, 14 feet 2 inches in diameter and 9 feet 9 inches in length.

The batteries on the *Kasagi* are heavier than those on either of the United States cruisers *Minneapolis* or *Columbia*. There are two 8-inch rifles at the sides, and her armament besides will consist of ten 4.7-inch quick-firing rifles, mounted in broadsides; a secondary battery of twelve 12-pounder quick-firing rifles and six 2.5-inch Hotchkiss guns. When the vessel is handed over to the Japanese government, five torpedo tubes, 14 inches in diameter, will be mounted.

There are two steel masts on the *Kasagi*. These will be provided with fighting tops in which rapid-firing guns will be placed. The vessel will be equipped with four powerful searchlights, and there will be eight steering stations to provide for almost any contingency. The engines will be protected by solid steel hatches.

The contract for the *Kasagi* was signed with representatives of the Japanese government on December 31, 1896.

Chitose.—The launch of this vessel at the Union Iron Works, San Francisco, on the 22d of January, followed closely that of the other Japanese cruiser, the *Kasagi*, at Cramps. The following data for the *Chitose* were kindly supplied by Messrs. Howard Gage and Leo Morgan, members of the Society.

Second-class unarmored protected cruiser. Contract signed at Washington, D. C., December 31, 1896. First piece of keel was laid May 1, 1897. First rivet driven June 26, 1897. Launched January 22, 1898.

Length over all, feet and inches	405–2
Length, loadwater line, feet and inches	396–0
Length, between perpendiculars, feet and inches	376–5
Breadth, moulded, feet and inches	49–0
Draught, normal, feet and inches	17–7½
Displacement, tons	4,760
Speed, knots	22½
I.H.P.	15,500
Coal capacity (total) tons	1,000

Armament: two 8-inch quick-firing guns; ten 4.7-inch quick-firing guns; twelve 12-pounder quick-firing guns; six 2½-pounder quick-firing guns; five 14-inch torpedo tubes.

Engines, twin screws. One four-cylinder, triple-expansion engine on each screw.

H.P. cylinder, diameter, inches	40
I.P. cylinder, diameter, inches	60
Two L.P. cylinders, diameter, each, inches	66
Stroke, inches	36
Revolutions per minute	150

Piston valves on H.P. cylinder; slides on I.P. and L.P.; cast steel bed plates; forged steel framing.

Main Boilers.—Twelve single-ended, cylindrical, four-furnace boilers. Working pressure 155 pounds.

ONE BOILER.

Mean diameter, feet and inches	14–0
Length over heads, feet and inches	9–3¾
Number of furnaces	4
Diameter of furnaces, Least, feet and inches	2–10
Diameter of furnaces, Greatest, feet and inches	3–2
Thickness, inches	½
Number of combustion chambers to each boiler	2.
Thickness of combustion chamber sheets, inches	$\frac{9}{16}$
Heating surface:	
430 2½-inch charcoal iron tubes, square feet	1,540.8
4 furnaces, square feet	140.2
2 combustion chambers	248.0
Heating surface, one boiler, square feet	1,929.
Heating surface, twelve boilers, square feet	23,148.
Area through tubes, one boiler, square feet	9.12
Grate area, one boiler, square feet	66.00
Ratio H.S. to G.S.	29.2 to 1.
Steam capacity 5 inches above top of combustion chamber, cubic feet	296.5
Morrison's suspension furnaces used.	
Thickness of shell plates, inches	$1\frac{1}{16}$
Thickness of top parts of heads, inch	1
Thickness of tube sheets, inch	¾
Thickness of bottom parts of heads, inch	¾
Closed fire room forced draft.	

Akashi.—The following account of the *Akashi*, which was launched at the Yokoska shipbuilding yard in December, 1897, and is a sister vessel, we believe, to the *Suma*, which was

launched from the same yard about two years ago, is abridged from "Engineering." The Yokoska shipbuilding yard, which is situated a few miles below Yokohama, was under the charge of French engineers and shipbuilders for a good many years, but now it is entirely managed by Japanese, who, after having studied in their own country, extended their practical knowledge in some of the largest shipbuilding yards in Europe. A graduate of the Imperial College of Engineering, Tokyo, who was for a good many years one of the superintending engineers at Yokoska, has just gone to England for the purpose of acting as inspector of the engines which are being built there for the Japanese war ships.

The *Akashi* is a steel twin-screw cruiser of 295 feet in length, 41 feet 7.5 inches beam, 15 feet 8.5 inches draught, 2,800 tons displacement, and 8,000 horse power. It is expected that she will attain a speed of 19.5 knots. Her coal bunkers have a capacity for 600 tons, and her armament, when completed, will consist of six 12-centimeter quick-firing guns, two 15-centimeter quick-firers, four machine guns, and two torpedo tubes; the six 12-centimeter in sponsons, three of which are constructed on either side of the ship, the two 15-centimeter guns being mounted behind shields, fore and aft. The difficulty of shipbuilding in Japan, especially for the Navy, will be understood when it is remembered that practically all the steel used in construction requires to be imported, and therefore that much of the special work which engineers and shipbuilders elsewhere get done at outside establishments, requires to be done in the yard at Yokoska. Even with the cheap labor of Japan, it is evident that the cost of production must be much greater than in a well organized shipbuilding yard in Europe or America; but the Japanese are willing to pay for their experience.

Shipbuilding for Japan in Europe.—Japan appears to be bent upon becoming the primary Naval Power of the East, and it has been stated that, building as she is at the present rate, in ten years time she will be able to dominate both Russia and the United States in the Pacific Ocean. The total list of the ships now being built for her is reckoned to be four battleships, eleven cruisers,

twelve torpedo-boat destroyers, and a similar number of torpedo boats. Of these, five armored ships are under contract at the works of Messrs. Armstrong, Whitworth & Co., and four torpedo-boat destroyers, 30-knot boats of the most formidable and modern type, are building at the Yarrow Works, and four more at Messrs. Thornycroft's. Of the five vessels building at the Armstrong Works, three are battleships, one of 14,800 tons, and two of 12,200 tons, a first-class armored cruiser of 9,600 tons, and a fast protected cruiser of 4,300 tons. The Thames Ironworks Co. have also a battleship in hand for the Japanese Navy, and Messrs. Thompson, of Clydebank, are building one, both vessels of 14,800 tons. On the Continent, Japan has building a torpedo-boat destroyer and eight torpedo boats at the Schichau Works in Germany, and four other torpedo boats at the Normand Works in France. A cruiser of 9,600 tons is building at the Vulcan Works, Stettin, and another in France. Contracts for several other vessels are to be given out shortly. Thus it can be seen that Japan is rapidly becoming a formidable sea Power. When these vessels have all hoisted the pennant, Japan will have a navy strong enough to hold its own against more than one of the European Powers.

RUSSIA.

Svetlana.—(Already noticed on page 188 of JOURNAL for 1897.)—The new Russian protected cruiser *Svetlana*, which has just been completed at Havre, has many special features about her, the chief being that she is a powerful, speedy and effective man-of-war, and is also a comfortable private yacht. The official designation of her is "a cruiser at the disposal of the Grand Duke High Admiral." Her dimensions are: Length, 331 feet 4 inches; beam, 42 feet 8 inches; depth, 33 feet 9 inches; extreme draught, 18 feet 9 inches, and displacement 3,828 tons. She is built of steel and sheathed with wood and copper. She is fitted with two powerful engines of the vertical triple-expansion type, driving twin screws, and is expected to attain a speed of close on 21 knots an hour. Her engines were estimated to develop 8,500 H.P., but have already exceeded this by 100, and at the final steam trials it is calculated that they will reach 10,000 H.P. She has eighteen Belleville boilers in three

groups of six each. With full bunkers she will have a radius of 12,000 miles at 10 knots speed. She has already undergone her preliminary coal consumption trials, but her splendid interior fittings and appliances still require much to be done to them before she is completed. Although the *Svetlana* is so luxuriously furnished throughout, all the appliances that modern ingenuity can devise have been used to make her an efficient fighting machine. Her armor consists of a protective deck and glacis, the latter covering the engines. Above the armor deck, which stretches the ship's entire length, is a cofferdam surrounding the vessel. This cofferdam contains an automatic device in use in the Russian Navy for stopping shell perforations. Her two sets of engines are entirely separated by a longitudinal bulkhead, and the three sets of boilers are in separate compartments, which plentifully subdivide the hull. She has a wonderfully strong armament, and is said to carry more powder and shell than any other vessel of her class.

SPAIN.

Pluton—Proserpina.—The official trials of the Spanish torpedo-boat destroyer *Pluton*, constructed by the Clydebank Engineering and Shipbuilding Company, Limited, to the order of the Spanish Government, have been successfully completed. The *Pluton* is 225 feet long, and is thus somewhat larger than the latest class of British torpedo-boat destroyers. She is, therefore, enabled to carry a considerably greater dead weight, the actual load on board during the trials being 73 tons. The results of the trial gave a mean speed of 30.12 knots on the measured mile, and during a continuous run of one and one-half hours a speed of 30.02 knots was maintained. At the conclusion of the forced-draft trial the vessel was, according to contract, run for a further period of two hours under natural draft, the speed attained being 22.7 knots, or 0.7 knot over the contract. During the tests there was a noticeable absence of vibration, and the engines worked to the entire satisfaction of the Spanish Commission. A sister ship, the *Proserpina*, has been launched from the Clydebank yard.

MERCHANT STEAMERS.

Kaiser Wilhelm der Grosse.—(Data of this vessel have appeared in several recent issues of the JOURNAL, but the present account is the most complete thus far published. It is from the "Marine Engineer.")—She has the distinction of being, at the moment, the largest vessel afloat, and she may also claim the record for speed on the Atlantic, even if the weather which has prevailed since she came out has not allowed her to lower the record in every detail. She is essentially a German product. She was built at Stettin by the Vulcan Co., which has turned out for the North German Lloyd Co. such vessels as the *Kaiser Wilhelm II*, the *Havel* and the *Spree;* and for the Hamburg-American Co. the *Augusta Victoria* and the *Fürst Bismarck.*

The *Kaiser Wilhelm der Grosse* is, of course, built of steel. She has a straight stem, and an elliptical stern, and has four funnels, placed in two groups of two, and a couple of masts, which are really little more than exaggerated signal poles. The hull is fitted with bilge keels to minimize rolling, and the rudder is entirely under water, so as to render its disablement in action difficult. This last because the construction of the vessel has been undertaken with a view to make her, as far as possible, a useful auxiliary to the German War Navy in time of national stress. The hull is also built, in regard to strength and scantlings, in accordance with the requirements of the German Lloyd. The vessel's displacement at load draught is no less than 20,000 tons, which is about 33 per cent. above that of the largest vessel in the British Navy. Her gross tonnage is about 14,000 tons. This is 1,000 tons more than that of the big Cunarders. The ship being 648 feet in length over all, is 24 feet longer than the *Campania.* She is 66 feet beam, and 43 feet deep from keel to main deck. Her great hull is divided into seventeen compartments by sixteen transverse bulkheads, and there are longitudinal

bulkheads between the two sets of engines. The vessel has a double bottom for her entire length, and her boilers are placed in four separate compartments, so as to ensure, as far as possible, that no stranding or collision shall deprive the propelling machinery and pumps of a due supply of steam.

The upper decks have been specially strengthened to carry quick-firing guns. The deck uppermost of all is the navigation and boat deck. It extends for nearly 400 feet amidships, and forms a permanent awning over the passengers' promenade. On this boat deck are carried no less than twenty-four boats. Here, too, are the chart house, wheel house, and officers' quarters, so that the navigation staff can carry out their duties without any possible interruption from the crowds of passengers who throng the lower decks. Going down to the promenade deck, we find that there is a sheltered walk of 400 feet in length for the saloon passengers. Forward of this there is a short waist, where the emigrant can take the air on the spar deck, and forward of that a long forecastle, with a couple of breakwaters upon it, and spare stockless anchors. The second-class passengers have the promenade aft on the poop. In the deckhouse on the promenade deck forward is the writing room. Then come a number of very luxurious suites of rooms, and reading and ladies' rooms. Aft of these is the smoking room, a horse-shoe shaped apartment, handsomely decorated in the German style.

The vessel having saloon accommodation for some 400 passengers, in 200 staterooms, there is naturally a very large saloon, for passengers nowadays object to taking their meals in relays. The difficulty of giving a large saloon without interfering with the bukheading of the ship is got over by making the saloon amidships as large as the bulkheads will allow, and by making four subsidiary saloons, named, respectively, the Königin Luise, the Kaiserin Augusta, the Möltke and the Bismarck, open out of it. These smaller saloons seat about 30 passengers each, and can be shut off in case of need by water tight doors. The vessel is manned by a crew of 450 men. The captain is aided by a navigating officer as well as by the ordinary mates.

The machinery consists of two sets of triple-expansion engines,

balanced on the Schlick system. Each set contains a high pressure cylinder 52 inches inches in diameter, an intermediate of 89¾ inches, and two low pressure cylinders of 96½ inches each. The stroke is 69 inches. The four cranks are set at angles of 100 degrees, 100 degrees, 100 degrees and 60 degrees, respectively. There are two three-bladed screws, weighing 26 tons each. They are 22 feet 4 inches in diameter and 32 feet 8 inches pitch.

There are twelve double-ended boilers in the four groups, and each group has a funnel 12 feet 2 inches in diameter, rising 106 feet above the furnace bars. The shafting is of nickel steel, from the Krupp Foundry, and is 198 feet long and 24 inches in diameter. There are two condensers with a cooling surface of 35,522 square feet. They contain 11,000 tubes, whose total length would amount to something over 30 miles. There is an installation of sixteen ventilating fans, for working the vessel under forced draft. The centrifugal and other pumps, capable of being put on the bilge, are equal to the duty of discharging 3,600 tons of water from the ship per hour. There are four large dynamos for electric lighting, which is, of course, installed all over the ship; and there is also a refrigerating installation. Altogether, with steering apparatus and sanitary pumps, there are no less than 68 separate engines with 124 cylinders aboard the vessel.

As regards her performance, it may be said that on her first voyage she captured the Southampton-New York record from the *St. Paul*, with a crossing of five days twenty-two hours forty-five minutes. Her mean speed across was 21.38 knots, and her best day's steaming was 564 nautical miles, which was the best day's run ever made by any vessel. On her third outward trip, she left the Needles at 4.30 P. M. on the 10th November, and reached Sandy Hook at 1.20 P. M. on the 16th, making the passage in six days one hour and three minutes. The daily runs were 436, 513, 434, 531, 549, 567 and 26 miles. Total distance steamed, 3,055 nautical miles. Mean speed, 21.06 knots. Her best day increased her own record by three miles for a day's steaming, and showed a mean speed for the day of 22.83 knots.

The homeward log is given in full, as it shows the best mean speed ever attained on an eastward voyage by any steamer.

ABSTRACT OF LOG.

Passed Sandy Hook Lightship November 23d, 4.47 P. M.
Arrived Needles Lighthouse November 29th, 3.10 P. M., 1897.

Date.	*Miles.*	*Lat. N.*	*Lon. W.*	*Remarks.*
Nov. 24th.	401	41.27	65.12	Overcast; snow squalls; rough sea.
Nov. 25th.	520	44.12	54.2	Cloudy; moderate sea.
Nov. 26th.	513	47.3	42.31	Mostly overcast; moderate sea.
Nov. 27th.	528	49.24	39.48	Cloudy; smooth sea; northerly swell.
Nov. 28th.	525	50 0	16.19	Rain squalls; moderate high W. sea.
Nov. 29th.	507	50.14	3.16	Heavy squalls; very high N. W. sea.
Nov. 29th.	71 to Needles.			Gale from N. W.

Passage, 5 days, 22 hours, 23 minutes.
Distance, 3,065 miles. Difference in time, 4 hours 50 minutes.
Delayed by a burning ship, 25 minutes.
Time of passage, 5 days, 17 hours, 8 minutes.
Average speed, 22.35 knots.

Ward Line Steamers.—A contract has been placed by the New York & Cuba Mail Steamship Company, generally known as the Ward Line, with the William Cramp & Sons' Ship and Engine Building Company, for two new steamers, which, when completed, will rank with the finest vessels ever launched from American shipyards. The construction of these vessels is a result of the new Government mail contract, which required that the company provide sixteen-knot boats. Work has already been commenced on the new vessels, and the first is to be ready for service about October next, the second following later.

They will be 500 register ton vessels, 360 feet long between perpendiculars, or about 400 feet over all; 50 feet beam; with 32 feet depth of hold and 21 feet draught when loaded. They will probably be the most expensive steamers of their size and for their trade afloat. They will resemble in many respects the St. Paul and St. Louis of the American Line, and will, in fact, virtually be ocean liners, with the improvements required for the coasting trade. They are to be twin-screw vessels, and will also have two stacks, differing in this respect from the present steamers of the line. They will have triple-expansion engines, four boilers of 5,000 horse power, giving them a speed when loaded of sixteen knots, this speed to be maintained when in actual service as well as on trial trips. Each will have five hatches and six sideports, thus insuring rapid handling of cargo.

There will be passenger accommodations on each of the new vessels for about 140 first and second cabin passengers. The cabin quarters will be amidships on the hurricane deck, and each stateroom, which will be $9 \times 6\frac{1}{2}$ feet, will be an outside room with entrances from the interior of the vesssel. The second cabin quarters will be aft on the hurricane deck. This arrangement gives up the fore and aft of the vessels to cargo. There will be a smoking room on the bridge deck without going outside. It is unnecessary to say that the vessels will be equipped with electric lights and that the passenger accommodation will have every improvement, both for safety and convenience, of a modern first-class steamer. In accordance with the contract with the Government, the new vessels are to be serviceable as auxiliary cruisers. They must be of sufficient strength and capacity to carry and sustain the working of a battery of twelve rifled cannon, of a caliber not less than six inches. Special attention will be paid to the protection of the machinery, the coal bunkers being placed so that none of the main machinery will be within 10 feet of the sides of the vessel. The names of the new steamers have not been selected. The vessels are intended for the regular Cuban and Mexican service of the line.—"Seaboard."

Large Lake Steamer.—Captain John Mitchell and others have concluded negotiations with the Globe Iron Works Company of Cleveland, Ohio, for the construction of a large steel steamer for freight service which will excel all other vessels on the great lakes as regards economy of fuel consumption.

The vessel will be 438 feet over all, 410 feet between perpendiculars, 50 feet beam, and 28 feet molded depth. Work on the boat will be begun within a few days, and it will be ready for service during July, unless unforeseen difficulties delay the construction. The boat will be equipped with quadruple expansion engines, three Scotch boilers, 12 feet by 12 feet, and will be fitted with Ellis and Eaves' draft, Serve's tubes, corrugated or Morison's suspension furnaces. The motive power of the famous steamer *Inchmona* is, in fact, being applied to the Mitchell boat. The same system in part has been placed in one or two lake steamers, but the immense expense has precluded its adoption in

full. The steamer *Inchmona*, which is employed in ocean service between European and Australian ports, is said to consume only one pound of coal per indicated horse power per hour.

The new boat will consume considerably less fuel than the steamer *L. C. Waldo*, which makes the round trip from Lake Erie to Duluth with 160 tons of slack coal.

The performance of the steamer *Waldo* gives a good idea of of what is expected of the Mitchell steamer. The *Waldo* consumes 3,546 pounds of coal per hour, according to a table showing the performances of modern lake steamers. The consumption per indicated horse power per hour was 1.71 pounds and the consumption per mile per ton of cargo was .063 pound.

The steamer *Waldo's* record will be beaten, but the performance of the remarkable sea-going vessel may not be reached. However, it is expected that the adoption of the system mentioned will enable the lake boat to come very near to equaling the performance of the steamer *Inchmona*.—"Marine Review."

China.—Early in the morning of December 23, 1897, the Pacific Mail steamer *China* passed in through the Golden Gate, having broken all previous records for the run across the Pacific and winning for herself the distinction of having made the fastest sustained speed for twenty-four hours of any steamship that has ever crossed the Pacific ocean. The performance of the steamer is the more remarkable because she was forced to fight against strong southeast gales for many days. The *China* arrived here 14 days 12 hours and 18 minutes from Yokohama. The run up from Honolulu was made in 5 days 7 hours and 36 minutes. The running time from Yokohama to Honolulu was 8 days 6 hours and 15 minutes, being an average of 410.75 knots a day or 17.1 knots an hour. She arrived in Honolulu three days ahead of schedule time, and beat all previous records for the run of 3,393 miles by 1 day, one hour and 40 minutes. Her daily runs in knots were: 400, 411, 417, 401, 400, 400, 404, 400 and 160. The maximum speed developed was 18.85 knots an hour. During the twenty-four hours beginning at midnight December 11, the steamer covered a distance of 427 knots by observation, this being the best run ever made by a steamship

on the Pacific Ocean. The best previous record between Honolulu and San Francisco was made in September, 1896, by the *China*, the time being 5 days 8 hours and 29 minutes.

Boadicea.—On Thursday, November 25th, Messrs. Alex. Stephen & Sons launched, at Linthouse, a large four-masted steamer, built to the order of Messrs. Furness, Withy & Co., Limited, and to be run by the Wilsons, and Furness-Leyland Line, Limited, of London, in their weekly passenger line between London and New York. The vessel is also fitted for the cattle trade, and is capable of carrying cargo to the extent of about 8,500 tons deadweight, or about 15,500 measurement tons. She has been constructed under Lloyd's rules for the 100 A1 three-deck-rule class, with many extras in excess of their requirements, and also conforms with the Board of Trade rules for passenger certificate. She has three complete steel decks besides the shelter deck, which is also of steel amidships, sheathed with yellow pine. There are nine water-tight bulkheads, and double-bottom fore and aft, forming the ballast tanks. The dimensions of the hull are: Length, over all, 500 feet; breadth, 52 feet 3 inches; depth, moulded, from upper deck, 34 feet 6 inches. Accommodation for 150 first-class passengers is provided in a large bridge house on top of shelter deck (the bridge extending the whole breadth of the ship), and a large deck house on top of this extending nearly the whole of the bridge, but leaving a passage of about 7 feet at side, over which the promenade deck is carried, forming a sheltered promenade.

On the shelter deck—which is the working deck of the steamer—are fitted cargo-working appliances of the most efficient type. The combined hand and steam steering gear is placed in a wheel house on shelter deck aft, and has been supplied by Hastie, of Greenock. Electric light, supplied by Messrs. W. C. Martin & Co., is fitted throughout the entire vessel; and the whole of the living accommodation is heated by steam, and baths and wash basins in the lavatories are supplied with both hot and cold water. "Pyles" ingenious heaters are used, in which the water is heated by steam as it runs full-bore through the supply pipe. The galley is airy, well lighted, and

fitted with large cooking range, bakers' oven and all other modern appliances. The pantry, which adjoins the saloon, is also of ample size, and contains hot press, tea and coffee boilers, etc. On deck below the passenger accommodation, and entirely separated from it in every way, is the provision for carrying cattle. It is sufficient for about 700 head, and is of the most improved and modern type, fully satisfying both British and American conditions.

The machinery consists of one set of triple-expansion engines, having cylinders 32 inches, 54 inches and 90 inches diameter, respectively, by 66 inches stroke, each cylinder being fitted with a liner and separate valve face. Balance pistons are fitted to the I.P. and L.P. slide valves. The crank shaft is of forged ingot steel. The condenser has a very large cooling surface, and is made in Messrs. Stephens' usual style, viz: of steel plates, circular in form, a method greatly superior to the ordinary cast condenser, as it is practically impossible to break it. A large centrifugal pump for circulating purposes is fitted, of Drysdale & Co.'s make, having two separate engines, each being capable of driving the pump at full speed. A jet injection is also fitted to the condenser. The air pump and two bilge pumps are worked off the L.P. crosshead. There are no feed pumps on the main engines, two Weir's pumps being fitted of large capacity.

A large auxiliary duplex pump with gunmetal water end, of Clarke, Chapman & Co.'s make, is also fitted and is constructed so as to act as a testing pump for boilers when required. Another duplex pump of Clarke, Chapman & Co. acts as a fire extinguishing pump, and also as a fresh water pump for cattle purposes. A hand pump (which can be worked when desired by the main engines) is also fitted. A large pulsometer forms the ballast pump, which is capable of emptying the entire ballast tanks of the ship in a very short time. There is a forty-ton Quiggin's evaporator, which is also capable of acting as condenser for the exhaust steam from the winches and auxiliary engines. A pulsometer is attached to the evaporator for circulating purposes. The feed water filter for arresting all grease and oil in the feed water is Quiggin's patent. The propeller has four blades of

Parson's manganese bronze, Manganese Bronze Co.'s own make, The deck machinery consists of nine winches of Clarke, Chapman & Co.'s make, one with 10-inch cylinders by 16-inch stroke; one 8-inch cylinders by 2-inch stroke, and seven 7-inch cylinders by 12-inch stroke.

The boilers are four in number, two double ended and two single ended, working at a pressure of 180 pounds. They are fitted with Henderson's patent rocking fire bars, and have ample heating and grate surface for 5,000 H.P. at sea. Large ventilators have been fitted to the stokeholds. All labor saving appliances possible have been fitted, such as steam reversing gear, steam turning gear, steam ash hoists, etc. In short, the whole machinery has been designed and fitted so as to give the highest results both in efficiency and in economy in labor and fuel. A heavy list of spare gear, covering nearly all working parts of the machinery, has been supplied.

Avon.—(A partial description of this British coasting vessel was given in the last number of the JOURNAL. The following account is condensed from one in "Engineering.")

The twin-screw steamer *Avon*, was built and engined by Messrs. Wigham Richardson and Co., Newcastle-on-Tyne, for the Carron Company's line of passenger steamers between London and the Firth of Forth.

The *Avon* is of 1,722 tons gross, and 471 tons net, register, being 290 feet long between perpendiculars, 37½ feet beam, and 18 feet 8 inches depth molded to main deck. She is classed 100 A1 at Lloyds'.

Amongst the requirements for the Carron Company's service, which are of a very exacting nature, are a high rate of speed, to enable the vessels to keep time, which must be arranged to suit the tides, and a large cargo measurement on a limited draft of water. The *Avon's* deadweight capacity is about 1,150 tons on 17 feet 9 inches draft. She has large cargo ports and gangway doors for loading and coaling, and her three cargo hatchways are served by four of Brown's steam and hydraulic cranes. The steering gear is also by Messrs. Brown Brothers, fitted on the rudder head and controlled from the captain's bridge by their well-known

telemotor gear. The deck machinery includes Napier's steam windlass, and two special warping winches by Messrs. Clarke, Chapman and Co.

The propelling machinery consists of two sets of independent engines with twin screws. Steam is supplied by five boilers, two being placed forward and two aft of a common cross-bunker, while the fifth, or auxiliary, boiler is placed in a recess in the cross-bunker. The four large boilers are each 15 feet 3 inches in diameter by 11 feet 6 inches long, and are fitted with Fox's patent furnaces and Howden's forced draft, the air being supplied by two large fans placed in a continuation of the bunker recess referred to above. A See's ash ejector is fitted in each of the two stokeholds, by which the ashes are discharged from the stokehold in a stream of water through pipes leading directly overboard, and for which a special powerful duplex donkey is provided. The noise and discomfort usually accompanying the discharging of ashes are thus entirely avoided.

The main engines are of the four-crank triple-expansion type, balanced on the Yarrow, Schlick and Tweedy system. The high and intermediate-pressure cylinders are 23½ inches and 38 inches in diameter, respectively, and the two low-pressure each 43 inches in diameter, the stroke being 36 inches. The cylinders are supported at the front by four cast-iron columns to which the piston-rod guides are attached, and at the back by six vertical wrought-iron pillars so disposed as to give free access to the crank pins, bearings, etc. The crank shafts are of Siemens-Martin ingot steel, made in two interchangeable parts by Messrs. Beardmore & Co. Each shaft is supported by six bearings of large surface, and lined with white brass.

Steam is supplied to the high-pressure cylinder past the inner edges of a piston valve, while the exhaust passes over the ends of the same valve into the outer space of the piston valve of the intermediate-pressure cylinder. This valve is of the Trick type, having the exhaust in the inside, from which the steam is led to the slide valves of the low-pressure cylinders by copper pipes. The valves are worked by double eccentrics and link motion in the usual way, and the reversing gear is of Brown's patent steam

and hydraulic type. The hand gear for reversing, as well as for the stopping and starting valves, drain cocks, etc., for both engines, is conveniently grouped at the after end of the engine room. A Brown's emergency governor is fitted to each reversing engine. Each engine is provided with a separate steam turning gear, the main wheel of which is keyed to the couplings joining the two parts of the crank shaft, while the worm shaft is carried up to the second-motion shaft, and the steam engine placed above the middle platform, thus leaving the lower platform quite free, and the bearings, eccentrics, etc., accessible for overhauling.

Each engine has a separate surface condenser of cylindrical form placed at the side of the ship close under the deck, and connected at each end by short copper pipes to the low-pressure cylinders. A separate centrifugal pump by Messrs. Drysdale & Co., of Glasgow, is placed below each condenser. The air pumps are of the usual type, and are worked by levers and links from the crosshead of the after low-pressure engines, the levers being supported on bearings bolted to the top of the cast-iron air vessels, which, in turn are firmly fixed to the bed plates at their lower ends, and steadied at their upper ends by brackets screwed to the adjacent columns.

At the after end of the engine room, a pair of Weir's automatic feed pumps are placed, fitted with all of Messrs. Weir's latest improvements. The feed water may be passed directly into the boilers from the pumps, or diverted into a feed heater placed on the deck at the forward end of the engine room. In addition to the Weir's feed pumps, there is a large duplex pump by Messrs. Carruthers & Co., for feeding and general purposes, and also two pumps by the same makers for fresh water and sanitary purposes. The ballast donkey pump is by Messrs. Watson & Sons, and is of the Patterson type, the special feature being the valve motion, which is designed to secure a steady and, if necessary, a quick movement of the plungers without risk of knocking at the end of the stroke. For pumps of this class, and, indeed, in all pumps, it is most important that the pump should travel the full length of the designed stroke, and in order to give the pump valves time to seat themselves, a slight pause should

take place before the return stroke commences, and with the Patterson valve gear these requirements have been successfully realized. All the auxiliary machinery is arranged to exhaust into a special surface condenser placed on the port side of the forward stokehold.

To return again to the main engines. Hitherto, the cylinders of four-crank triple-expansion engines have almost invariably been arranged in the sequence, high-pressure, intermediate pressure, low pressure, low-pressure; whereas in the *Avon*, and also in the *Innisfallen*, designed by Mr. Tweedy in 1895, and completed last year by Messrs. Wigham Richardson & Co., the low-pressure cylinders are placed outside of the high-pressure and intermediate pressure, *i. e.*, in the following order: Low-pressure, high-pressure, intermediate-pressure, and low-pressure. Dr. Kirk, in his three-crank compound engines, placed the high-pressure between the two low-pressure cylinders, and in large triple-expansion engines, a common arrangement is to place tandem cylinders over the two outer low-pressure cylinders; but the object aimed at in the present case is quite different from that which previous designers had in view, and, as far as we are aware, is quite new. The *Innisfallen* referred to above is probably the first four-crank triple-expansion engine built in this way. It is to be noted that it is not in itself sufficient to place the low-pressure cylinders outside in order to obtain a satisfactory result, for, although the turning moments might be about the same as in the best ordinary engines, the tendency to vibrate the ship, and rack the engines themselves, might even be greater.

On a lengthened trial trip the speed of the *Avon* was ascertained to be 17.38 knots in unfavorable weather. At the highest number of revolutions—over 130 per minute—the vessel was found to be perfectly free from vibrations, and there was none of that straining and racking of the engines so common in high-speed machinery. It is probably due, also, to the remarkable smoothness of their working on the occasion of a trial run made in the presence of Sir W. H. White and Sir John Durston, that engines of the same design will be fitted in the royal yacht which is to be built at the Pembroke Dockyard.

Floating Dock for Stettin.—Alarge *floating dry dock* capable of lifting a 15,000-ton vessel has been ordered by the Vulcan Shipbuilding & Engineering Co., of Stettin, from C. S. Swan & Hunter, of England. The first use which will be made of this dock will be the lengthening of the North German Lloyd liners *Spree* and *Havel.*

Spree and **Havel.** — These ships are about six years old. They are now 463 feet long, 51 feet 10 inches beam, and 37 feet deep. An additional 65 feet will be built in amidships, bringing the length up to 528 feet. A more radical change, however, will be the substitution of two sets of engines driving twin screws for the single engines and screw of each vessel. The present engines are of the five-cylinder, three-crank, triple-expansion type, indicating about 11,500 horse power. The new engines will be four-cylinder, four-crank, triple-expansion, each vessel having about 18,000 horse power. Three new boilers will also be fitted in each vessel. An extra knot and a half is expected as a result of the alterations.

These vessels were built and engined by the Vulcan Company of Stettin, some seven years ago. The engines were of the five-cylinder, triple-expansion type, and the speed and economy of the steamers have never been questioned. But the single screw was adopted in the case of these vessels and it was a mistake which the directors of the company now frankly and wisely admit and seek to remedy. The last argument, feeble as it is, is now taken away from those British Mail Companies which, in pursuance of a penny-wise policy, continue to turn out single-screw ships. They said that the fact that the North German Lloyd built the *Spree* and *Havel* on this principle justified them in their continuing to build their ships in the same way. The many recent vessels which North German Lloyd have added to their fleet have all been twin-screws, and that, of course, showed that the company had realized its mistake. But the intention to alter these modern vessels is a very strong accentuation of their belief in the absolute necessity of duplication of machinery in mail and passenger steamers.—" Marine Engineer."

Monarch.—On Tuesday morning, October 12th, the steamer

Monarch, built by C. S. Swan & Hunter, Limited, Wallsend, left her mooring at the builders' yard and was taken to sea to undergo her trials. Like her sister ship, the *Milwaukee*, she is one of the most complete cargo steamers ever built. Her dimensions are 484 feet over all, 470 feet between perpendiculars, 56 feet beam, and 42 feet 3 inches depth to the shelter deck. She has a carrying capacity of 11,700 tons deadweight, or a measurement capacity of upwards of 18,000 tons, and is fitted for the conveyance of a large number of cattle in the 'tween decks, with cattle stalls of the latest type and most approved arrangement of water service. For rapidly handling the very large cargoes which the steamer will carry, an exceptional number of powerful winches, together with derrick posts and derricks, have been placed in convenient positions about the decks. It not being intended to carry passengers, the accommodation, which will be placed on the shade deck, is of a very limited, although very comfortable description. Water ballast will be carried in the double bottom throughout the vessel and also in a deep midship tank, the total quantity amounting to about 3,000 tons; fresh water can also be carried in some of these tanks for the use of cattle; fresh water condensers, which can work at all hours, will also keep up the necessary supply of fresh water.

The propelling machinery has been constructed and supplied by the Wallsend Slipway & Engineering Co., of Wallsend, and consists of a set of engines having cylinders 28½ inches, 46½ inches and 80 inches diameter, respectively, by 54 inches stroke; the steam is supplied at 180 pounds pressure by three large boilers fitted with Howden's system of forced draft, and the propeller has manganese bronze blades. In addition to Lloyd's classification and extra scantlings beyond their requirements, the steamer has been constructed under the supervision of the Board of Trade and to the requirements of the German law, so as to adapt her for any trade and to enable her to be taken up at any time as a passenger steamer.

Briton.—This is the largest steamer that has ever left a British port for a British colony. The work of constructing the vessel commenced on September 12, 1896, and she was launched in

June last. The *Briton* was built by Messrs. Harland & Wolff, and when completed for sea her total weight would be 17,700 tons, and her net tonnage 10,300 tons. Her length between perpendiculars is 544 feet; breadth, 60 feet; depth from keel to upper deck, 40 feet. The ship's twin screws are driven by triple-expansion engines of 10,000 H.P., and a speed of 13 knots an hour is looked for. The consumption of coal to feed the forty-eight furnaces of her seven boilers between Southampton and the Cape is estimated at some 2,500 tons. The *Briton's* crew numbers 237 hands all told, while she will be able to accommodate 904 passengers, there being berths for 300 in the first class, 200 second class, and 300 third class.

Idaho.—The latest addition to the already very numerous fleet of Messrs. Thomas Wilson, Sons and Co., of Hull, was launched by Messrs. C. S. Swan and Hunter, Limited, of Wallsend, on October 26. This vessel has been built for the Atlantic cattle and cargo trade, and she is also intended to carry a limited number of first-class passengers. Her dimensions are 470 feet over all, 460 feet between perpendiculars, by 50 feet beam and 42 feet 6 inches depth molded. Water ballast will be carried, as usual, in the double bottom and in the peak tanks, and the large cargo, which will amount to over 8,000 tons deadweight, will be manipulated by a large number of very powerful steam winches. Accommodation for the passengers, officers, etc., will be placed in steel houses on the shelter deck amidships, and the vessel will be fitted up in the 'tween decks with Wylies' patent fittings for 600 head of cattle with all the latest arrangements for their comfort and ample water supply, etc. The machinery has been constructed by the Wallsend Slipway and Engineering Company, Limited, of Wallsend, and will consist of a set of engines of the latest type, having cylinders 31 inches, 52 inches and 91 inches in diameter by 60 inches stroke, supplied with steam by four boilers, two double-ended and two single-ended, with a total heating surface of 12,500 square feet; working pressure, 200 pounds, Howden's forced draft arrangements and fittings being applied. It is expected that the *Idaho* will steam at 14 knots.

Carisbrook Castle.—The Fairfield Shipbuilding and Engi-

neering Company, Limited, launched, on October 28, 1897, a new Castle Liner, the *Carisbrook Castle*, a screw steamer of about 7,500 tons gross and 8,500 indicated horse power, built for the South African Royal Mail Service of the Castle Line. The vessel, which will be the largest in the company's fleet, is 500 feet long over all, and 480 feet on the water line. Her extreme breadth is 56 feet, and her moulded depth, 35 feet 6 inches. There is a cellular double bottom the full length of the ship, and the holds have been subdivided into separate compartments by water-tight bulkheads, which are constructed and arranged with the object of meeting the recommendations of the Bulkhead Committee. When completed, the vessel will accommodate about 250 first-class passengers amidships, 150 second-class aft, and about 220 third-class forward.

The cabin accommodation is chiefly on the main, upper and bridge decks. On the latter deck are some single berth state-rooms, and also several cabins for officers of the vessel. The dining saloon will be paneled in oak, and will have a handsome domed cupola in the center, with electric ventilating fans. The drawing room, on the forward part of the promenade deck, will be paneled with inlaid mahogany, and provided with elegant cabinets, lounges, easy chairs and writing tables. The smoking room, at the after end of the first-class promenade deck, will be finished in wainscot oak, with large square ventilating windows at the sides. Needless to say, the equipment is most complete.

The propelling machinery consists of four cylinder and four crank quadruple-expansion engines, balanced on the Yarrow, Schlick, Tweedy system. The right to use this particular type of engine has been acquired by the company because of the advantages it affords in reducing the vibration of the ship. The boiler pressure is 205 pounds per square inch, and the machinery has been designed with a view to obtaining the maximum economy of fuel practicable with this high pressure, combined with high speed. Special attention has been given to reducing noise and vibration in the engine room, centrifugal pumps, driven by electric motors which are absolutely noiseless, being adopted for the hot and cold sea-water supply to the baths, the sanitary service, &c.

YACHTS.

Standart.—(Previous notices have appeared in the JOURNAL, Vol. VII, p. 434, and Vol. IX, pp. 189 and 436. The following account is from "Engineering" of January 28, where it is accompanied by illustrations.)—On December 26, 1896, the new Russian Imperial yacht *Standart* left the shipyard of Messrs. Burmeister and Wain, Copenhagen, bound for Libau. The vessel was commenced in 1893, when the first rivet was driven by the late Tsar Alexander III, and the launch took place on March 10, 1895. The vessel was designed and built under the inspection of Chief Constructor Dolgoroukow and Chief Engineer Pastouchoff, of the Russian Imperial Navy. The *Standart* is a twin-screw vessel, 370 feet between perpendiculars; her breadth is 50 feet 8 inches; her depth moulded, 36 feet; the load draught is 20 feet; and the displacement, 5,255 tons. She is rigged as a three-masted schooner, and has three decks, two funnels and a clipper stem. The vessel is built of mild steel on the longitudinal cellular bottom principle, the water-ballast compartments containing 460 tons of water. The twenty-four Belleville water-tube boilers are placed in two rows back to back in two boiler spaces separated by a water-tight transverse bulkhead, twelve boilers in each space. The coal bunkers are arranged partially at the sides of the boiler spaces, partially forward of these, their capacity being about 850 tons. The length of machinery space is 168 feet, 125 feet being occupied by the boilers, and 43 feet by the engines. The communication between the boiler and engine rooms is established by means of water-tight doors.

As to the construction of the hull, the following data may be of interest. The framing consists of Z-bars, the frame spacing being 35 inches amidships and 30 inches at ends. The stem, sternpost and propeller brackets are of cast steel. Large bosses are constructed round the propeller shaft, but the shell plating

is formed as if the bosses did not exist, and a special plating is carried over these bosses outside. In this way the tunnel can be kept free from water in case of any injury to the plating of the bosses. The rudder is constructed in the ordinary way with a frame of forged steel. The hull is divided into a large number of water-tight compartments, whilst to reduce rolling large bilge keels are fitted running nearly half the length of the ship. The polemasts are of steel with topmasts of Oregon pine. Two out of the three decks are of steel, covered with pitch pine and teak on all parts exposed to weather. The windlass, which has cylinders 9 inches in diameter by 9 inches stroke, has been supplied by Messrs. Harfield and Co. The anchors are of ordinary type with stock. The *Standart* has twelve boats, of which four are steam launches about 40 feet long. The boat davits are worked by worm gearing. The armament consits of eight 47-millimeter quick-firing Hotchkiss guns, intended for saluting; these were made in Russia, and are nickel-plated all over.

As above mentioned, the *Standart* was built as a yacht for the Russian Emperor, a fact which necessarily had much influence in selecting the different fittings. The imperial apartments are situated on the main deck abaft the engine space, where are placed rooms for the Emperor and Empress, as well as for the Dowager Empress. For each of these, three rooms are arranged, viz: a sitting room, a bed room, and a bath room. Here also are to be found the Imperial drawing and dining rooms. Further aft, the rooms for four Grand Dukes and Grand Duchesses are situated. On both sides of the boiler space are situated the staterooms for the officers. The great mess room for the officers will be found forward of the boiler space. The Imperial kitchen is situated between the two funnel casings.

On the lower deck aft, there are rooms for the Imperial children and the suite. On both sides of the engine-boiler space the artificers and the servants are berthed, and forward of these rooms the crew space is situated. On this deck also the rooms for the dynamos and bath rooms for the crew are located. On the platform deck, there are rooms for the petty officers and servants, as well as a workshop for the engineers, luggage room, cable

room and pantry. The hold between the shaft passages is arranged to store provisions and wine, and can be kept cool by means of a complete refrigerating plant, the walls being isolated by charcoal. In the forehold there are also store rooms for provisions, a powder magazine and the chain lockers. On the upper deck aft a large deck house, about 100 feet long, is erected, the top of which forms a fine promenade deck. The galley for the officers and the crew is situated between the funnels. Forward of the foremost funnel we find the chart house, containing everything necessary for the navigation of the ship, and two deck cabins for the chief commander. On top of this are placed the wheel house and the flying bridge.

The ship is lighted by electricity, about 1,070 lamps being fixed in the various rooms and corridors. The top and side lights are also electric, the lamps being doubled in such a way that if one breaks, another will begin to glow, and at the same time a lamp in the chart room automatically shows which lamp is broken. The completeness of the electric fittings is well shown by the fact that the total length of copper wires on board is about 18 miles. The dynamos with their engines are placed on the lower deck. The total effective horse power is 250, distributed as follows: Two triple-expansion engines of 100-horse power each, and one compound engine of 50-horse power, the two larger engines having cylinders of 10 inches, 16 inches, and 22½ inches in diameter by 8 inches stroke, and running at 220 revolutions per minute. The smaller one has cylinders 8¾ inches and 13¾ inches in diameter by 8 inches stroke, and runs at 250 revolutions per minute. Besides the dynamos, two small accumulator batteries are arranged, which can supply a special set of lamps all over the ship in case of damage to the dynamos. For the joiner work in cabins the most costly woods have been used. For the Imperial rooms, for instance, solid cherry; for the Empress Dowager's rooms, birch; in the Grand Duke's compartments, birch; in the drawing room, walnut; in the Imperial dining room, ash; in the corridors, oak, bird's-eye maple, white beech, In the crew space the joiner work is made of oak and pine, the latter painted with white enamel. In the Imperial rooms the

walls are covered with pressed leather, cretonne and silk. No gilding whatever is used, on account of a special wish expressed by the late Emperor. A few words ought to be said about the windows on the main deck. These are constructed with two round lights, which, together with the plates in which they are set, swing open horizontally; the inner window is formed of two thick plate-glass panes in gun-metal frames, hinged like French windows, the whole being nickel-plated. A most elaborate system of copper piping, tinned inside, supplies all parts of the ship with fresh water, the tanks being placed abaft the engine space and in the forward hold. From this system washstands, baths and lavatories are supplied. The fresh-water pipes are fed by two duplex 6-inch Worthington pumps, the overflow being collected by a tank on the upper deck. A branch from the fresh-water main goes through a steam-heating apparatus, from which it distributes hot water to all parts of the ship. Besides these a salt-water system supplies the baths, wash rooms and water closets, and at the same time the fire hose. The heating of the ship is carried out by means of hot water. This water is raised to a temperature of about 125 degrees, partly by steam from the boilers and partly by the waste steam from the Worthington pumps, used to circulate the hot water, an expansion tank being placed in the chart room. Special attention has been paid to the matter of ventilation. Besides ordinary cowls, thirteen electro-motors are used to circulate air in the ventilating trunks.

The boilers are of Belleville's 1894 model. Their total grate area is 1,116 square feet, and the heating surface 35,250 square feet. Each boiler contains ten elements with ten rows of tubes in each. The tubes are of solid-drawn steel 6 feet 9½ inches long. The pressure in the boilers is 245 pounds per square inch, and the working pressure 165 pounds, the lowering being effected by means of two reducing valves for the main engines, and four others for the auxiliaries. The feed pumps alone make use of the full boiler pressure. Eight double-sided fans of 6 feet 3 inches diameter, with engines having cylinders 8½ inches in diameter by 6 inches stroke, are fitted for supplying forced draft to the boilers. The draft is led below the stokehold flat, and

here it can be passed either into the stokehold, or, if desired, directly to the ashpits by means of shutters in front of the boilers. The air pressure used is 1 inch of water and the fans can give 320 tons of air per hour. The weight of the boilers is 680 tons; this includes pipes, spare gear, and all fittings in the boiler room. The two funnels are of 11 feet internal and 13 feet 6 inches external diameter, their tops being about 68 feet above the furnace bars. The space between the outer and inner funnel serves to ventilate not only the boiler space, but also the crew space, and gives room for the four waste-steam pipes. Each boiler space is furnished with four feed pumps. These pumps are special ones of the Belleville type, and have 16¼-inch steam cylinders, the stroke being 10½ inches. To remove the ashes from the boiler spaces, four See's 6-inch ash ejectors are placed in the stokeholds. The water is supplied by two duplex pumps of 5 inches diameter with steam cylinders of 8 inches diameter by 8 inches stroke. In harbors where the ash ejectors would be objectionable, four ash-hoisting engines are used, the ash buckets running between guides in the boiler room ventilators.

The propelling engines are twin and of the triple expansion type. The diameters of the cylinders are 41⅛ inches, 65⅛ inches, 105⅛ inches, and the stroke 54 inches. The high-pressure and intermediate cylinders are fitted with piston valves, the latter having two valves, and the low-pressure cylinders are fitted with double-ported Trick slide valves, with relief rings on the back. The slides are worked by eccentrics in the ordinary way, the two intermediate slides having a common crosshead. The slide valve of each cylinder can be notched up separately. The starting engines, which have an all-round motion, are placed at the forward end of the main engines, and have two cylinders 8 inches in diameter by 6 inches stroke. The turning engines have the same dimensions as the starting engines; they swing on two trunnions, the live steam entering on one side and the waste steam leaving on the other. These engines turn the main engines once round in about 2½ minutes. The main engine cylinders are jacketed on the sides, as well as on top and bottom, the steam pressure in the jacket being 165 pounds for the high-pressure

cylinder, 75 pounds for the intermediate, and 15 pounds for the low-pressure cylinder. The drainage from the steam jackets is collected by an automatic steam trap.

The front columns and the high-pressure back columns form oil reservoirs. The crank shaft is of steel, and is built up of three interchangeable pieces. The shafts have an 8-inch hole through them, the outside diameters being 17½ inches and 18 inches. The main condensers are made of cast iron, being cast in one with the back standards of the intermediate and low-pressure cylinders. Two centrifugal pumps supply the condensers with cooling water. These are run by vertical compound engines, having cylinders 9½ inches and 14¾ inches in diameter by 8½ inches stroke. Their crankshafts are coupled direct to the fan shafts of the centrifugal pumps. The fans are 3 feet 6 inches in diameter, and each pump can deliver 1,000 tons per hour. The suctions can be arranged to draw from the engine and boiler-rooms in case they are flooded. An auxiliary condenser, entirely of brass, is placed in the engine room for the purpose of condensing the steam used by the auxiliary engines through the ship; it is fitted with a compound engine working pumps for delivering the condensed steam into the feed tanks and circulating the cooling water. The cooling area of each of the two main condensers is 9,000 square feet, that of the auxiliary condenser 1,500 square feet. The condenser tubes are of solid-drawn brass. The air pumps are worked by levers from the crossheads of the high-pressure cylinders, which also work the bilge pumps and oil pumps, which draw the waste oil from the save-alls, sending it to the oil filters.

The propellers have three blades each, and are 16 feet in diameter, with 27 feet pitch. This pitch can be varied 2 feet either way. The blades and bosses are made of Delta metal, and the studs of phosphor-bronze. Two bilge pumps are fitted in the engine room, and can draw from all the water tanks, the holds and the sea. They deliver the water to the bath rooms, to the deck and to the tanks for the feed pumps, and can act also as fire pumps. The steam cylinders are 6 inches in diameter by 6 inches stroke, the pump cylinder being 4 inches in diameter.

Two 7-inch bilge centrifugal pumps of 1 foot 8 inches in diameter, intended for use in case of serious damage to the vessel, are placed below the engine-room floor. The shafts, about 20 feet long, are vertical and reach to the upper engine gallery, where the engines, which have cylinders of 5 inches in diameter by 6 inches stroke, are placed so that the water level in the engine room may be very high before the action of the pumps is interfered with. Besides these pumps, which may be used as fire pumps, two other pumps are provided specially for this purpose, and have a total capacity of 60 tons per hour.

In the double bottom the *Standart* carries 154 tons of fresh water, but this not being sufficient for the boilers, the ship has been furnished with a distilling appartus. The water is circulated through the condensers by two vertical duplex pumps, each of which has two auxiliary plungers fitted, of which the one sends salt water to the evaporator, and the other one the fresh water from the condensers to the fresh-water tanks. The steam from the evaporators can also be sent direct to the main and auxiliary condensers. The capacity of this plant is about 60 tons of fresh water in twenty-four hours.

The hydraulic steering gear of Messrs. Brown Brothers has been adopted, and consists of their well known telemoter combined with a compound engine, having cylinders 9 inches and 15½ inches in diameter by 12 inches stroke, working the hydraulic pumps, with an accumulator, the working pressure being 50 atmospheres.

The contract for the *Standart* stipulated that she should be able to maintain an average speed of 20 knots for twelve consecutive hours, the mean draught of the ship being 20 feet. On actual trial her speed, on a twelve hours' run, was 21.5 knots on an average, and during this time her performance over a measured distance of 27.5 nautical miles showed a speed of 21.75 knots, the runs being made both ways in order to eliminate the influence of currents and tides. The dynamos and other auxiliary machinery were running all the time; the main engines averaged 12,000 indicated horse power throughout the trial.

Payne Yacht.—The Bath Iron Works have contracted to

build for Col. O. H. Payne, of New York, a yacht which will be larger than the *Eleanor*, built by this firm in 1893-4, and at present the largest American built yacht afloat. The Payne yacht is modeled generally after the *Eleanor*. It will be bark rigged, with a spread of 17,000 square feet of sails, and a single engine of 3,200-horse power, giving an estimated speed of 16 knots, with a displacement of 1,300 tons.

The hull is of mild steel, with following dimensions:

Length over all, feet	301.
Length at load water line, feet	258.
Beam at load water line, feet and inches	36–6
Moulded depth at side, feet and inches	21–4
Depth of hold, feet	20.
Mean draught, feet	15.
Draught aft, feet and inches	15–9
Displacement at load draught, tons (about)	1,300

There are two decks and a superstructure, seven water-tight bulkheads, with double bottoms in fore and after holds, but none in the machinery space. There is a trimming tank forward, and six water tanks aft, capable of carrying thirty tons of fresh water. The machinery space and bunkers occupy 96 feet of length. Forward of this are commodions quarters for the ship's officers and crew. Aft are six guests' and two servants' rooms, with five bath rooms. The forward and after holds contain cold storage rooms, wine lockers, and ship's and engineer's stores. The deck house is of steel, with mahogany sheathing, and is 150 feet long. A passage way an either side, six feet wide, gives a clear sweep of the deck from forward aft. The owner's room, 16 feet by 15 feet, and two large guest rooms, with separate baths, are in the after part of the deck house, and a large dining room, 30 feet by 18 feet, occupies the forward part, a steam laundry, pantry, galley and fire room hatch being between. A side passage connects the quarters aft with the dining room. The chart house and a smoking room are above, forward of the promenade deck.

There are four coal bunkers, with a total capacity of 460 tons, enabling the vessel to steam about 5,000 miles at 12 knots speed. One bunker, of 140 tons, extends athwartship, forward of the boiler compartment; another, of 280 tons, separates the engine

and boiler compartments, with a passage amidships; and two bunkers, of 20 tons each, extend along the boiler compartment, one on each side.

The engine is of the vertical, inverted, direct-acting, triple-expansion, three-cylinder type; cylinders, 28 inches, 43¼ inches and 70 inches, with a stroke of 38 inches. The arrangement from forward aft is, I.P. cylinder, I.P. piston valve, H.P. piston valve, H.P. cylinder, L.P. slide valve, and L P. cylinder, the whole being in line. The engines are designed to develop 3,200 horse power, with 135 revolutions and 165 pounds steam pressure. The Stephenson link motion is used. The bedplate is in one pieee, cast iron, 22 feet long and 11 wide (the largest casting ever made here). The back columns, A-shaped, are of cast steel, and the front vertical I-columns are iron forgings. The crank shafts and pins, 12⅜ inches, line shaft, 12¼ inches, and propeller shaft, 13⅛ inches, are solid forged. An ordinary horse-shoe thrust of nine collars (58 pounds indicated thrust per square inch of surface) is used. A clutch coupling and small thrust is fitted aft, to allow the screw to revolve when the engine is not in use. The propeller is of manganese bronze, with four detachable blades, and is 13 feet in diameter.

There is one condenser, of cast iron or plates built up, and ⅝-inch tinned composition tubes, having a cooling surface of 4,000 square feet. All pumps are independent. The circulating pump is a centrifugal pump with 11-inch nozzle, and a simple engine of 400 revolutions, 7½ inches diameter and 6-inch stroke. There are two pumps for fire, feed and bilge pumps (type not yet determined). Other auxiliaries (all in the engine room) are an ice machine, a distiller and evaporator, electric plant, steam-steering engine and a ventilating fan (Sturtevant blower). A steam windlass and capstan on the forcastle and one aft on the quarter deck (with engine below deck), complete the auxiliaries. In the after hold is a storage battery, capable of lighting the vessel twelve hours.

There are four single-end Scotch boilers, 14 feet 4 inches diameter and 12 feet long, 1 1/16-inch shells, placed two abreast, with an athwartship fire room between. Each boiler has three corru-

gated furnaces (Morison suspension type), 44-inches diameter, a grate surface of 80 square feet, 360 tubes, 2½ inches diameter and 8 feet 6 inches long, and a total heating surface of 2,372.84 square feet. Ratio of heating surface to grate surface, 29.6. There is no arrangement for forced draft.

The lower masts and yards are of pine, the bowsprit of steel and the other spars of spruce. The yacht will carry two 25-foot launches, two whaleboats, one gig and one dingey. The wood work is in cherry, ash and mahogany, and the interior is to be handsomely furnished.

The work will be under the personal supervision of the captain and chief engineer of the yacht, and will be completed by March 1, 1899.—(Contributed by P. A. Engr. W. H. McGrann, U. S. N.)

Niagara.—This steel, twin-screw steam yacht is being built by the Harlan & Hollingsworth Company, of Wilmington, Del., for Howard Gould, Esq., of New York. She is nearing completion and was launched February 19th.

PRINCIPAL DIMENSIONS.

Length over all, feet and inches	272–4.5
Length between perpendiculars, (Lloyd's) feet and inches	247–6
Breadth, moulded, feet	36
Depth to spar deck at sides, feet and inches	27–5
Depth to spar deck at center, feet and inches	28–2
Depth, moulded, to main deck at center, feet and inches	19–6
Draught at trial speed, feet and inches	16–9

Her displacement will be about 2,088 short tons. Her I.H.P. will be about 2,000, and she is to make fourteen knots on a six-hour trial, with 400 tons of coal and ordinary stores on board, but with no water in water bottom. She will be bark rigged, with mast and yards of wood; standing gear being of steel rope, and the running of hemp and manila. The vessel will be equipped with nine yacht boats and two launches complete.

Hull.—This is generally of steel of best quality, with scantlings to entitle the yacht to Lloyds' highest classification. The keel is of the center through-plate type; stem of hammered steel, and stern frame of cast steel, with rudder bosses and pro-

jecting keel. The rudder frame with cross bars is a solid iron forging.

The after part departs from usual construction in that tunnels with diminishing cross-sections and consequent fair runs, on the Lundborg system, are built in the structure to support and inclose the shafts up to the propellers. This construction does away with the ordinary brackets, and makes those parts of the shafts which usually run in water accessible from inner spaces at all times. This is the same system of shaft tubing that the American liners *St. Paul* and *St. Louis* are provided with.

A water bottom extends from the forward bulkhead aft, and water-tight bulkheads and flats divide the yacht into seven water-tight compartments, with necessary sluice valves and drainage system. The bunkers are capable of holding about 425 tons of coal. The deck fittings will be of the newest and best description, and the superstructures, saloons and living quarters generally will be in design and finish suitable for a yacht of this class. The owner's quarters are all forward, consisting of six staterooms on main deck and four on the lower deck, with the dining saloon on the main deck forward of the boilers. On this same deck are the library, on the starboard side, and the pantry and kitchen, on the port side. On the spar deck are the captain's stateroom and chart room, with the ladies' saloon just abaft. In the deck house the owner's room is aft and the smoking room amidships. The crew are quartered aft on the lower deck, while the officers' quarters are on the deck above.

Main Engines.—There are two sets of engines on independent shafts. Each is of the inverted, three-cylinder, triple-expansion, direct acting, surface-condensing type; working pressure, 160 pounds per square inch; revolutions at trial speed, about 121. The cylinders are 18, 28 and 45 inches in diameter with a common stroke of 30 inches. All valves are of cast iron. Each high-pressure cylinder has a piston valve, and the intermediate and low-pressure cylinders, double ported slide valves. Each low-pressure valve is located between the intermediate and low-pressure cylinders, thus making the receiver which surrounds

the cylinders answer as steam chest for the low pressure cylinder. There are guides on backs of the intermediate and low-pressure valves to prevent them falling from their faces, and each is balanced for weight by a piston secured to the valve stem and working in a cylinder on top of chest cover.

The pistons are of cast iron, secured to rods by ordinary taper fit and nuts. Followers are of cast iron secured by steel follower bolts screwed into brass bushings tapped into the pistons. The packing for high-pressure and intermediate pistons is solid bull rings with narrow packing rings and springs. The low-pressure cylinders have each three rings, two outside and one inside, also set out with springs. Each bedplate is of cast iron, box form, with recesses for main pedestal boxes, six in number. The main guides are of the single-bar type, cast hollow for water circulation. Slippers are of composition with white metal linings. All principal wrought moving parts are of mild steel, except as may be otherwise stated. Each piston rod is 4 inches in diameter, and secured to its crosshead by a nut at lower end. The rods have metallic packing.

The connecting rods have strap, gib and keys, at the upper ends, and bolts and caps at the lower. They are 68 inches from center to center of journals, and 4 and $4\frac{3}{4}$ inches at upper and lower necks respectively. The boxes at crosshead end are unlined composition, and at the crank pin, composition lined with white metal. The valve stems are $2\frac{5}{8}$ inches in diameter with bolt connections at the link blocks. All stems have metallic packing. The links are of the double-bar type, with eccentric pins forced and riveted into the bars. Link blocks are of steel with adjustable gibs.

The eccentric rods are of hammered iron, with forked ends, and strap, gib and key connections at the links. The eccentrics and straps are of cast iron, the latter being lined with white metal. Each eccentric is secured to shaft by feather and set screws, and allowance made on each side of feather for adjustment of the lead by liners. The eccentrics of the intermediate and low-pressure valves are in two pieces and the high-pressure in one.

The crank shaft is of the built-up type, with bearings and pins $8\frac{3}{4}$ inches in diameter by 9 inches in length. The line shafting is $8\frac{1}{2}$, the thrust shaft $8\frac{3}{4}$, and the tail shaft 9 inches in diameter. The propeller shaft has brass sleeves where it extends through stern pipe, and the part not thus covered is painted and wrapped with marline. The stern pipes are of cast iron bored at both ends to receive brass sleeves containing lignum vitæ.

Thrust bearings are of the horse-shoe type, having cast-iron collars lined with Parsons' white brass. There is a gland at each end to insure the collars running in oil.

All shaft bearings are lined with Parsons' white brass; those for line shafting being of cast iron, and those for crank shafts and pins of composition.

The condensers form part of each engine by housings extending up and bolting to the cylinders. Tube sheets are of rolled brass $1\frac{1}{8}$ inches thick, with rolled brass supporting plate in center. Tubes: drawn, $\frac{3}{4}$-inch brass, tinned inside and out, and with 1,700 square feet of cooling surface for each condenser. They are in two nests. The circulating water enters at the top and, after passing through the upper nest, returns through the lower and out at the bottom. Packing: screw ferrule with cotton laces. Arrangement is made so that the condensers can work as jets in case of necessity.

There is a circulating-pump for each engine, with brass fan and shaft, driven by a 6-inch × 6-inch engine. Each is fitted with bilge connection and non-return valves. Each air-pump, worked by steel plate beam from intermediate crosshead, is 20 inches diameter and 12 inches stroke. The bucket, barrel, foot-valve and delivery-valve gratings are of composition. Rod is of steel, covered by brass sleeve. Valves are of hard rubber. There is a filter tank for each engine. There are two vertical duplex feed-pumps, with $7\frac{1}{2}$-inch steam cylinder, 5-inch water cylinder and 8-inch stroke. Pump valves are of brass. The pumps are arranged with automatic controling device attached to filter tanks. There are two bilge-pumps, bolted to the air pump of each engine and worked from the air pump crosshead. They,

as well as the main donkey pump, are connected to a manifold in the engine room leading to each compartment of the vessel.

Each propeller is four-bladed, built-up, the blades being secured by wrought-iron bolts and brass nuts. The material is cast iron with the addition of 20 per cent. of steel. Each is secured to shafts by taper and nut and key, with water-tight cap over the nut. The pitch is 13 feet, the diameter 10 feet, and the helicoidal area of each is 13½ square feet.

The throttles are of the double-balanced type, with brass valves, seats and stems. Main steam pipes are 7 inches internal diameter, and No. 4 B.W.G. thick. The reversing gear is of the ordinary vertical, direct-acting, steam-cylinder type. The engines can be turned by hand with pinch wheels having worm and ratchet attachments. There are the usual drain and water service pipes. Cranes are provided for lifting disconnected parts of machinery, where needed. The engine room is thoroughly equipped with all necessary tools, spare parts, etc.

Boilers.—There are three steel Scotch boilers, 13½ feet in diameter by 11½ feet long, inside of heads. All plates annealed after flanging and all rivet holes drilled. The shell sheets are 1⅛ inches thick. Circumferential seams are double riveted and butts are double butt-strapped and triple riveted. There are three corrugated furnaces in each boiler, 46 inches inside diameter. Tubes (iron) are 207 in number in each boiler, 3 inches diameter, and No. 9 B.W.G. Total heating surface, 6,273 square feet. Total grate surface, 207 square feet. Grate bars are of cast iron of ordinary type. There is no forced-draft system. Circulators are fitted to all boilers. There is one smoke pipe. The working pressure is 160 pounds.

Pipes.—All main steam, blow, air-pump discharge, feed, circulating, inlet and discharge pipes are of copper. Bilge pipes are of lead fitted with galvanized strainers. Small steam and exhaust and water service pipes are of brass.

Miscellaneous Machinery and Fittings.—One auxiliary surface condenser with independent horizontal air and circulating pump. This pump is connected with the water-bottom so that the trim of the ship may be regulated quickly. One duplex horizontal

donkey steam pump, to draw from bilge, water-ballast tanks, sea, hot-wells, condensers, and discharging overboard or into boilers or fire mains. One horizontal, duplex, donkey, steam pump, for flushing deck and fire purposes. One sanitary-pump, which can also be used to supply circulation for guides, etc. This has two water cylinders, one for salt and one for fresh water, with steam cylinder between. One deck hand-pump aft, drawing from bilge, and one forward drawing from forward water-tank. One hand pump in engine room for testing boilers and pumping bilges. Evaporator and distiller of fifteen tons capacity.

An electric-light plant of two direct-connected marine-type multipolar dynamos, each having a capacity of 400 16-c. p. lights. A storage battery of 40-light capacity. Complete heating system. Cold-storage plant of 1,500 cubic feet capacity, the refrigerating apparatus having an additional capacity of 200 pounds of ice per day. One steam windlass and capstan for chain and one steam-warping capstan. Steam steering-gear. Also, hand-steering gear of the right-and-left type. The vessel is fully equipped with all necessary engine and boiler-room instruments, bells, telegraphs, speaking tubes, etc.

Electra.—The steam yacht *Electra*, with the stern added in 1896, together with the new spars, machinery and other improvements introduced in 1897, is abreast to-day of the most modern steam yacht. The improvements of 1897 were made by the John N. Robins Co. at the Erie Basin from the plans and under the superintendence of Mr. Horace See, of New York City. The engines are of the triple-expansion variety, with cylinders 19, 28 and 42 inches diameter by 24 inches stroke of piston, driving a solid, manganese-bronze, propeller wheel. The entire shafting is made of steel, the cranks being provided with counter-balances. The condenser is of cylindrical form, fitted with horizontal composition tubes. The air-pump is vertical and driven off the cross-head of the high-pressure engine. The valves are of the piston variety, actuated by radial valve gear of the "See" pattern. The circulating and feed-pumps are independent, the latter being of the duplex variety working in connection with a filter. A complete evaporating apparatus is also fitted. The attention that has

been given to balancing the different parts of the machinery has brought about a complete relief from vibration of the hull.

The boilers are of the straight, subvertical, submerged, water-tube variety. They are two in number, with one forward and the other aft, arranged to be worked under either natural or forced draft. Under the latter condition the air, after having been heated by being drawn by the blower around the exposed surfaces of the boiler and casing, is forced into a closed ash pit. The tubes are of small diameter, made out of solid-drawn steel, and the drums entirely out of rolled steel. They are not only of simple form, but are so constructed that all parts can be readily examined, cleaned and repaired. Either bituminous or anthracite coal can be burned under them to the best advantage with a low air-pressure. During their first season's work they have demanded less repair than is customary with the Scotch boiler, although they have been required to get up steam in a very short time, have had the fires at a great heat, and have maintained the full steam pressure. The tubes and drums are to-day in as good condition as they were at the beginning of the season.

The proportions of the different parts of the boilers and their accessories are such that the combustion of the coal and absorption of the heat has been complete. The temperature of the escaping gases has been kept down to a point that has avoided the overheating of the smoke box and stack, whilst the steam pressure has at the same time been maintained when the engines were driving the vessel at the highest rate of speed.

In order to test the efficiency and endurance of the new machinery, a number of exhaustive trials were conducted with great success. The last one was run on November 13, in Long Island Sound during a gale. The effect of running at a speed of over 16 knots under these conditions was to deluge the deck and the bridge at times with water. The yacht and machinery, however, behaved splendidly during the entire run.—"Seaboard."

BOOK REVIEWS.

THE MARINE STEAM ENGINE, BY R. SENNETT AND H. J. ORAM. —Marine engineers whose academic education was completed before the issue of the first edition of Mr. Sennett's work will remember how it filled what was almost a vacuum in engineering literature. In other words, before its appearance, there was no adequate treatise on the marine engine, and students were compelled to depend upon lectures for their information. "Sennett," as the work was popularly called, changed all this and covered practically everything in the way of description and explanation that the student and young engineer wanted to know. So great was its success that a second edition was soon needed and issued in 1885. Not very long after this Mr. Sennett died, and the rapid progress and great changes in marine engineering during recent years have rendered many parts of the work obsolete.

Such a treatise revised to date was, however, needed and we now have it in the work with the title given above. Mr. H. J. Oram, who has, in revising the older work, practically rewritten it, is specially qualified for the task. After graduating as one of the most brilliant students at the Royal Naval College in 1882, he has been on duty in the office of the Engineer-in-chief of the Royal Navy and is now Senior Engineer Inspector at the Admiralty, his rank in the Royal Navy being Inspector of Machinery. His position has given him unusual opportunities for acquiring the most complete familiarity with all types of marine machinery. So much for the author; now for the work itself. Probably we shall give it sufficient praise if we say that it has preserved all the merits of the original work and added many of its own. Speaking generally, we may say that it covers thoroughly the subject of marine machinery in the way of description and explanation, and is so well illustrated that it seems no point has been overlooked. It has been brought fully down

to date, giving a very full account of water-tube boilers, feed-water heaters, evaporators, filters and all the latest features of modern machinery. If there is a fault, an American engineer would find it in the absence of descriptions of our own peculiar features, such as the independent air-pump, direct-acting steam pumps and the water-tube boilers designed on this side. It is to be remembered, however, that this work is designed primarily for British engineers and students, and, in a work of this kind, space is very limited. If great care had not been exercised in condensation of the text, the book would have become too bulky for a manual.

The illustrations are excellent and carefully drawn to give the most information. Another excellent feature for ready reference is the use of heavy-faced type for paragraph headings.

Without question, it is the best book published for giving an adequate acquaintance with marine machinery to the engineering student and young engineer, who must know this work before he can use that other indispensable manual, "Seaton."

The typographical features of the book are deserving of decided praise.

The work is published by Longmans, Green & Co., London and New York, and sold at $6.00.

MARINE REVIEW, of Cleveland, Ohio.—Shipbuilding number.—The enterprising publishers of this excellent paper, Messrs. Mulrooney & Barton, have made their issue of January 20th a special number, full of information, statistical and professional, and embellished with a number of fine illustrations, including photos of a number of the prominent men in shipbuilding, marine engineering and the allied interests, a colored photo of the *Kaiser Wilhelm der Grosse*, and one of the *St. Louis* and *St. Paul*. It is of interest to everybody connected with shipping, and should not only have a great circulation but be preserved for reference.

MECHANICAL DRAFT.—PUBLISHED BY THE B. F. STURTEVANT CO., BOSTON, MASS.—Although written to extend and advertise their business, the manufacture of fan blowers, this interesting work has a far higher merit than the usual trade catalogues,

valuable as they usually are nowadays. It covers a much wider field than the name indicates, for it discusses thoroughly the various fuels for boilers, the theory of combustion, efficiency of various boiler proportions, and chimney draft, as well as the subject of mechanical draft. It is not going too far to say that in no other single volume can as much information respecting all the conditions of burning fuel be found. It is well written and the author has evidently studied carefully all the literature on the subjects treated. It will undoubtedly have a wide circulation and become a recognized authority.

While a matter of minor importance, we are glad to see the spelling "draft" adopted. This has been the practice of the Bureau of Steam Engineering for the last ten years, "draught" relating to depth of water for vessels. We understand that the work is not for sale but is circulated gratuitously, and will doubtless be supplied to any engineer who applies to the Company.

OBITUARY.

In the present issue of the JOURNAL it is the sad duty of the Editor to announce the death of two of the young officers of the Engineer Corps who had recently entered the service with every prospect of a long and brilliant career in their chosen branch, but who have been cut off in the very beginning of that career under circumstances which cannot fail to attract the most sincerely sympathetic thoughts from every officer in the service.

JOHN SINGLETON PORTER

was born in Blount County, Tennessee, January 23d, 1873, and at the age of fifteen years was appointed to the Naval Academy from the Second Congressional District of his State.

He entered the Naval Academy September 25th, 1888, and was graduated in June, 1892, after having exhibited a brilliancy in his profession that was later considered when he was detailed to a special course at Paris.

He served on the *Baltimore* from July 1st, 1892, to June 13th, 1893; on the *San Francisco* from June 19th, 1893, to April 24th, 1894, and was on the latter vessel during her cruise to Rio de Janeiro as Flagship to Admiral Benham.

After final examination and two months' leave he was commissioned as an Assistant Engineer from July 1st, 1894.

He was on duty at the Navy Yard, New York, from August 14th to October 12th, 1894, and was then detailed for a special course at l'Ecole des Mines, and l'Ecole d'Application du Génie Maritime, Paris, where he remained until June 25th, 1896.

During his studies abroad his health became seriously impaired and he was given sick leave. He went to Denver, Col., to obtain relief for the lung trouble which had become rapidly more serious, and recently went to Phœnix, Arizona, hoping for good effects from that climate.

His personal letters to friends were so cheerful and hopeful that it was a shock to all to learn of his death, which occurred February 10th, 1898, at Phoenix, Arizona.

The Engineer Corps loses a brilliant young officer and the Navy has lost a member who was fitted to be one of the celebrities of the future.

DARWIN R. MERRITT

was born at Red Oak, Montgomery County, Iowa, April 12th, 1872.

In his nineteenth year he was appointed to the Naval Academy from the Ninth Congressional District of his State.

Having entered the Naval Academy September 10th, 1891, he completed his course there with much credit to himself and was graduated in June of 1895.

He served on the *Amphitrite* from June 24th to November 18th, 1895, after which time he was transferred to the *Indiana*, where he served till April 28th, 1897.

He returned to the Naval Academy for his final examinations, and was eminently successful in passing them, after which he was on leave for a period of two months.

He was commissioned as an assistant engineer from July 1st, 1897, and was stationed at the Navy Yard, New York, form September 10th to December 9th, last, when he was detailed to the *Maine*, where he has served since that time till his tragic death.

The name of this young officer was one of the first to be mentioned in the reports from Havana after the news of that terrible explosion on board the *Maine* on the night of Tuesday, February 15th, 1898, in the harbor of Havana. Since that time it has been impossible to gather full details of the manner of his death along with the hundreds of his shipmates who perished with him; but it is safe to say that he met his death with all the heroism that was exhibited by his more fortunate companions in their actions subsequent to the disaster, and we must accord to him and to them that praise which has so often fallen to the

lot of officers and men of our navy when they have been called upon to meet death in the performance of duty, or in the face of sudden and horrible disasters which meant nothing but useless sacrifice of life.

His death is memorable to a regretful country which honors him, and regretted by every member of the service in which he promised to be one of the best of its officers.

M. E. REED.

ANNUAL MEETING.

The annual meeting of the Society was held January 7th and 8th, 1898—the sessions for discussion of papers in the Lecture Hall of the Columbian University.

The first session was called to order at 2 P. M., January 7th, and in the absence of the President (due to illness), Chief Engineer H. Webster, U. S. N., was called to the chair.

The report of the Council awarding the prize for the best paper submitted in competition for it during the year, was presented and is as follows:

WASHINGTON, D. C., *January 7, 1898.*

To the American Society of Naval Engineers:

Gentlemen:—In accordance with the resolution adopted at the last annual meeting, January 9, 1897, the Council extended invitations to the Members and Associate Members to submit papers for competition, and asked their views on the adoption of a button or badge for the Society. The Council also made arrangements for a banquet and reunion, which will be held to-morrow night.

Several designs were submitted for a button, and, after careful consideration, the Council adopted a rosette of gilt and red for the official badge of the Society. The buttons were promised us on January 1st, but, unfortunately, have not yet arrived.

Regarding the award of a prize for the papers submitted for the annual competition, the Council takes great pleasure in awarding the first prize and a gold medal to the paper bearing the motto: "FACTS, NOT FICTION," the author of which is Passed Assistant Engineer W. W. White, U. S. N.

Very respectfully,

HAROLD P. NORTON,

Passed Assistant Engineer, U. S. N., for the Council.

Mr. White was then called to the platform and presented with the medal in a neat speech by the Chairman. He then read an abstract of his paper entitled "Steam Consumption of the Main and Auxiliary Machinery of the U. S. S. *Minneapolis*." It was discussed by Messrs. F. M. Wheeler, D. P. Jones, Emil Theiss, E. D. Meier, G. W. Baird and W. M. McFarland.

In the absence of the author, Mr. Irving Cox, Associate, his paper "American Steam Yachts," was read by Passed Assistant Engineer C. A. E. King, U. S. N., and briefly discussed by Messrs. J. A. Scott and John Platt.

Papers on "Trials of the Niclausse Safety Water-Tube Boiler," by Jay M. Whitham, Member, and "Water-Tube Boilers," by Darwin Almy, Associate, were then read by the Secretary, and they were discussed by Messrs. Ward, Platt, Edson, Meier, McFarland and Theiss.

"Boiler Testing with Various Fuels," by Col. David P. Jones, Member, was then read by the author, but the discussion postponed until the next session, in consequence of adjournment.

The business session was held on the evening of January 7th, in the office of the Engineer-in-Chief of the Navy, when Chief Engineer Geo. W. Baird was chosen chairman, owing to the illness of the President.

The report of the Secretary-Treasurer was submitted, showing the Society to be in excellent financial condition. It is as follows:

REPORT OF THE SECRETARY-TREASURER.

WASHINGTON, *January 7, 1898.*

To the American Society of Naval Engineers:

GENTLEMEN: In accordance with the requirements of Section 14 of the By-Laws of the Society, I have the honor to submit the following report on the financial condition of the Society from January 9, 1897, to date.

RECEIPTS.

Balance on hand, January 9, 1897	$4,282.21
Annual dues	1,894.29
Subscriptions, sales and reprints	807.02
Advertisements	1,226.40
General Index	197.50
Interest on deposit	89.73
	$8,497.15

EXPENDITURES.

Printing of JOURNAL	$2,035.06
Cost of General Index	200.15
Illustrations	285.12
Salary of Secretary-Treasurer	600.00
Stationery, postage and incidentals	154.83
Purchase of back numbers of JOURNAL	68.40
	$3,343.56
Balance on hand, January 7, 1898	$5,153.59

This balance is on deposit with the American Security and Trust Company.

Very respectfully,

F. C. BEIG, *Secretary-Treasurer.*

This report has, since the meeting, been audited and found correct.

The election of officers resulted as follows: President, Chief Engineer H. Webster, U. S. N.; Secretary-Treasurer, Passed Assistant-Engineer W. M. McFarland, U. S. N.; Council (in addition to these two officers), Chief-Engineer Geo. W. Baird, U. S. N.; Passed Assistant Engineer W. W. White, U. S. N.; Passed Assistant Engineer Emil Theiss, U. S. N.

A motion, offered by Passed Assistant Engineer B. C. Bryan, was adopted, making the winner of the prize for the best paper each year an honorary life member of the Society, so that the first one is Passed Assistant Engineer W. W. White, U. S. N.

Several resolutions were offered looking to modifications of the By-Laws of the Society, as a result of which the Council was directed, as provided in Section 21 of the By-Laws, to prepare a list of the proposed modifications and submit them to the members for inspection and vote.

A vote of thanks to the retiring officers was passed unanimously.

On the morning of the 8th, the visiting members and the ladies accompanying them were escorted to visit the Naval Gun Foundry, the new National Library, and other places of interest.

The second session for the reading and discussion of papers was held on the afternoon of January 8th.

The papers by Messrs. White and Jones, read on the 7th, were further discussed.

Mr. Frank B. King, Associate, then read his paper entitled "Speed of Construction, a Vital Factor in Naval Strength," which received much commendation, and was discussed by Messrs. Kafer, Jones, Theiss, Platt and McFarland.

Mr. John Platt, Associate, read his paper entitled "Trials of an Hydraulic Propelled Life Boat with Boiler Using Oil Fuel," which elicited much interest and a number of questions, which, however, owing to the novelty of the vessel, could not add any new matter to the paper.

A most important and interesting paper was then read by

Col. E. D. Meier, Associate, on "The Diesel Motor." There was a brief discussion by Messrs. Jones, Kafer, and Whitham, and others asked questions for further information.

Owing to the limited time remaining, the following papers were taken as read:

"Entropy and Entropy Diagrams," by Prof. W. F. Durand, Member. "The Submarine Boat Plunger," by J. Alvah Scott, Esq., Associate. "Speed and Power Trials of a Light Draught Steam Launch," by Charles Ward, Esq., Associate. "The Status of Boards on Changes in the Navy," by W. W. Varney, Esq., Associate.

A vote of thanks to the authorities of the Columbian University for their kindness in granting the use of the Lecture Hall was passed unanimously.

A motion was also unanimously adopted thanking the Council for arranging and managing the Annual Meeting, and congratulating them upon its great success, especially the Secretary-Treasurer, Passed Assistant Engineer F. C. Bieg, U. S. N., upon whom the burden of the work had devolved.

The first Banquet of the Society was held at the Maison Rauscher on the evening of the 8th, and was a most enjoyable occasion. On account of the illness of the president, Chief Engineer John C. Kafer, U. S. N., presided. Besides a graceful speech by the presiding officer, remarks were made by Col. David P. Jones (Chief Engineer, U. S. N., retired), J. J. de Kinder, Esq., Chief Engineer E. D. Robie, U. S. N., Jarvis B. Edson, Esq. (late Engineer Corps, U. S. N.), Chief Engineer H. Webster, U. S. N., Jay M. Whitham, Esq. (late Engineer Corps, U. S. N.), Passed Assistant Engineer F. C. Bieg, U. S. N., Charles Ward, Esq., and Passed Assistant Engineer W. M. McFarland, U. S. N.

This ended the Annual Meeting.

SPECIAL NOTICE.

To the Members and Associates:

In accordance with the resolution adopted on January 11, 1896, and amended on January 9, 1897, at the annual meeting of the American Society of Naval Engineers, the Council takes pleasure in offering for competition the sums of $75 and $25 respectively, and suitable medals for the best two original papers. The Council will

award "Honorable Mention" to such other papers as may deserve this distinction. The Council reserves the right to reject any or all papers.

By the broad terms of the resolution, a paper may be in the form of an original essay on any matter suitable for this Society, or it may be on the results of original experiment or research. There is no limit to the length of the papers, nor to the number of illustrations which may be thought necessary.

Papers must be original and submitted to the Secretary-Treasurer before the first of November of each year.

Papers receiving the award of "honorable mention" will be considered the property of the Society for publication in the JOURNAL.

Each paper submitted shall bear a motto chosen by the author, which shall be identified by a separate, sealed communication to the Secretary-Treasurer, giving the author's name and motto. These notes of identification shall be kept by the Secretary-Treasurer, and opened only after the Council has given its judgment on the papers. Then the prizes and "honorable mention" shall be awarded by name and the papers published in the JOURNAL.

The Council expresses the hope that members and associates will strive for the honors thus offered by the Society, and by their original productions enhance the value of the JOURNAL.

The button adopted for the Society is similar in general style to those of the various patriotic societies, with crimson and gold as colors. It will be sent to members and associates on receipt of thirty cents.

Papers to be read at the next Annual Meeting should be sent to the Secretary-Treasurer by November 1, 1898, in order that there may be time to have them printed and distributed for the preparation of discussion. Much time was lost at the recent meeting from the necessity of reading each paper, and the discussions could not be as thorough and valuable as if the papers had been in print and distributed beforehand.

The Council will be glad to receive any remarks in the way of discussion of the papers published in this number. They should be sent to the Secretary-Treasurer by May 1st.

NOTE.—The papers presented at the Annual Meeting which are not published in this number will appear in the May number.

AMERICAN SOCIETY OF NAVAL ENGINEERS.

OFFICERS FOR 1898.

President:

Chief Engineer **H. Webster**, U. S. Navy.

Secretary and Treasurer:

Passed Assistant Engineer **W. M. McFarland**, U. S. Navy.

Council:

Chief Engineer **H. Webster**, U. S. Navy.
Chief Engineer **G. W. Baird**, U. S. Navy.
Passed Assistant Engineer **W. M. McFarland**, U. S. Navy.
Passed Assistant Engineer **W. W. White**, U. S. Navy.
Passed Assistant Engineer **Emil Theiss**, U. S. Navy.

HONORARY MEMBERS.

(EX-OFFICIO.)

The Secretary of the Navy.

The Assistant Secretary of the Navy.

Chief of Bureau of Steam Engineering:

Geo. W. Melville, Engineer-in-Chief, U. S. N., Navy Department.

Ex-Chiefs of Bureau of Steam Engineering:

Chas. H. Haswell, Consulting and Superintending Engineer, 42 Broadway, New York.
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J. W. King, Chief Engineer, U. S. N. (retired), 3231 Powellton avenue, Philadelphia.
Chas. H. Loring, Chief Engineer, U. S. N. (retired), 239 Clermont avenue, Brooklyn.
Wm. H. Shock, Chief Engineer, U. S. N. (retired), 1404 15th street, Washington, D. C.

Prize Essayists.

W. W. White (1897), Passed Assistant Engineer U. S. N.,
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American Shipbuilder.....7 Coenties Slip, New York.

American Society of Mechanical Engineers.....12 West 31st street, New York.
Army and Navy Journal.....240 Broadway, New York.
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Association Technique Maritime.....8 Place de la Bourse, Paris, France.

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Cassier's Magazine.....World Building, New York.

Engineering.....35 Bedford street, Strand, London, England.
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Institution of Civil Engineers.....Great George street, Westminster, London, S. W., England.

Journal of the United States Artillery.....Fort Monroe, Va.

Literary Digest.....30 Lafayette Place, New York.

Marine Engineering.....World Building, New York.
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